

## ***Bush River Tributary Monitoring Scope of Work***

### ***Bush River Watershed nutrient and sediment sampling***

Increased population pressure and the resultant increase in anthropogenic sources of nutrients and sediment to the tidal waters of the Bush River have led to the Bush River being listed as critical impaired due to declining water quality in the tidal portion of the river. Tidal monitoring in the river supports this notion but is incapable of identifying the sources of the sediments and nutrients originating in the watershed. Non-tidal sampling, during base and storm flow events, at the lowest portion of the non-tidal sections of the main non-tidal tributaries discharging into the Bush River can help to identify primary contributions of nutrients and sediments from the watershed. This information can be used to target potential restoration sites (via targeting particular tributaries) as primary contributors of sediments and/or nutrients. Additionally, this information can be used to determine the successfulness of restoration efforts and best management practices occurring in the watershed and how it affects the downstream reaches and ultimately the quality of non-tidal waters discharging into the tidal Bush River.

**TASK 1:** Conduct non-tidal stream sampling in the Bush River watershed at six non-tidal sites under base flow conditions. Sites will be sampled biweekly to determine velocity (m<sup>3</sup>/sec), average stream width (m), average stream depth (m) for computing discharge, as well as collecting water quality samples. Grab samples will be collected just below the water surface at or near mid-stream. Biweekly samples will consist of a whole and a filtered component.

**TASK 2:** Collect weekly stream discharge measurements at each site to establish a discharge rating curve to allow estimation of watershed discharge. Water temperature, dissolved oxygen, pH, and conductivity will be measured in the field with a Hydrolab Surveyor II at the time of all water quality collections.

**TASK 3:** Conduct non-tidal stream sampling at six non-tidal sites under storm flow conditions using the U59 siphon samplers. Samples collected after storm events will be processed in the same manner as the biweekly samples. Additional measurements for velocity (m<sup>3</sup>/sec), average stream width (m), and average stream depth (m) will be collected via levelometers to allow for computing discharge will also be done in conjunction with storm event sampling.



**MARYLAND**  
DEPARTMENT OF  
NATURAL RESOURCES

**Robert L. Ehrlich, Jr.**  
*Governor*

**Michael S. Steele**  
*Lt. Governor*

**C. Ronald Franks**  
*Secretary*

**W.P. Jensen**  
*Deputy Secretary*

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# **2003 Bush River Shallow Water Monitoring Data Report**

September 21, 2004

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Prepared by:

Mark Trice, Ben Cole, Bruce Michael, Bill Romano, and Chris Heyer  
Resource Assessment Service/Tidewater Ecosystem Assessment  
Maryland Department of Natural Resources  
Tawes Building, D-2  
580 Taylor Avenue  
Annapolis, MD 21401

Website Address:

<http://dnr.maryland.gov>

Toll Free in Maryland:

1-877-620-8DNR, ext: 8630

Out of state call: 410-260-8630

TTY users call via the MD Relay:

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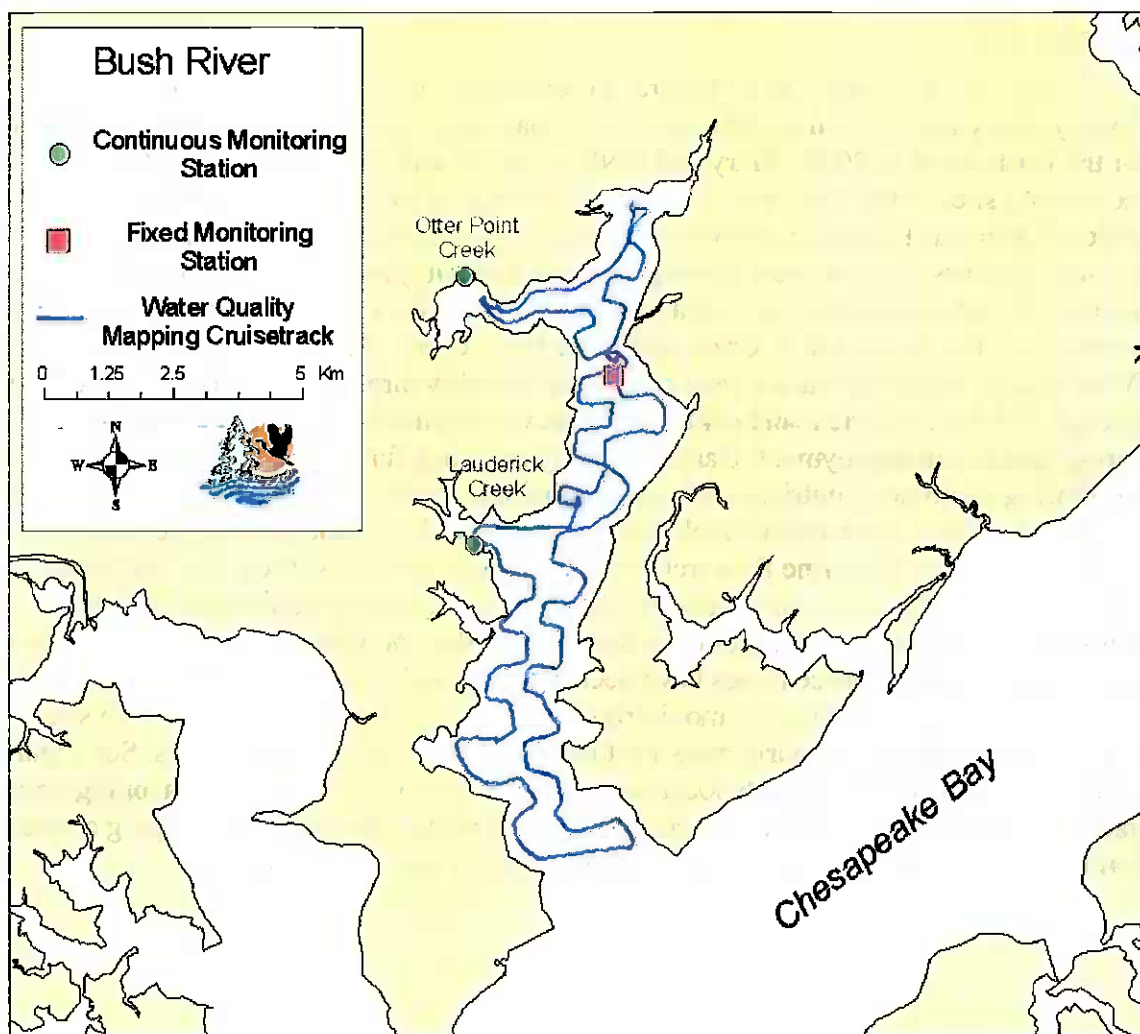
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## **Introduction**

The Maryland Department of Natural Resources (DNR) was contracted by Harford County, Maryland to conduct temporally and spatially intensive water quality monitoring for the Bush River in 2003. Maryland DNR deployed and maintained 24 continuous monitoring sites in the Chesapeake and Coastal Bays in 10 tributaries during 2003. The project's aim was to monitor ambient water quality parameters (water temperature, salinity, pH, dissolved oxygen, chlorophyll, and turbidity) in order to characterize water quality and habitat conditions. Continuous monitoring data were collected at 15-minute intervals at sites in Lauderick Creek and Otter Point Creek, April through October. Water quality mapping cruises were conducted monthly throughout the Bush River, May through October. Nutrient and calibration data were collected weekly by DNR staff during instrument deployment. Harford County provided funding for continuous monitoring equipment, nutrient analysis and maintenance of the site located on Lauderick Creek. The site at Otter Point Creek was funded through a cooperative agreement with NOAA's National Estuarine Research Reserve System (NERRS) Program. Although Harford County funded the purchase of YSI real-time telemetry equipment for 2003, software and communication problems from the vendors prevented the implementation of this feature in 2003. These issues have been resolved and real-time data is available for the Lauderick Creek continuous monitoring site on Dnr's "Eyes on the Bay" web site. Data are uploaded on an hourly basis for the full suite of physical parameters. See Figure 1 for continuous monitoring site locations and a sample of a water quality mapping cruise track. For a timeline of continuous monitoring site visits, water quality mapping cruises, harmful algal bloom samples and other timely information, see Table 1.



**Figure 1.** Site map and a sample water quality mapping cruisetrack for the Bush River monitoring project.

Dates	Lauderick Creek	Otter Pt. Creek	DataFlow Cruise Dates	Harmful Algal Sample	Other events and details
4/15/2003		X			
4/23/2003		X			
4/30/2003		X			
5/8/2003		X			
5/14/2003		X			
5/21/2003		X			
5/28/2003			X		
5/29/2003	X	X			
6/4/2003	X	X			
6/11/2003	X	X			
6/18/2003	X	X			
6/25/2003	X	X	X		
7/2/2003	X	X			
7/9/2003	X	X			
7/16/2003	X	X			
7/22/2003			X		
7/23/2003	X	X		X	Microcystis aeruginosa: 1.6 million (cells/ml) Anabaena sp. : 264,000 (cell/ml)
7/28/2003				X	Microcystis aeruginosa: 31.3 µg toxin/L (throughout the River)
7/30/2003	X	X			
8/6/2003	X	X			
8/13/2003	X	X		X	Microcystis: 24 µg toxin/L (upper reaches of the River)
8/20/2003	X	X			
8/26/2003			X		
8/27/2003	X	X			
9/2/2003		X			11:00 AM Continuous Monitoring ceased while deployment pier at Otter Creek Point was removed and rebuilt.
9/4/2003	X				
9/9/2003	X				
9/16/2003	X				
9/18/2003					Hurricane Isabel Landfall
9/22/2003					September 22-23, 2.4 inches of rain in 24 hrs
9/29/2003			X		
10/1/2003	X				
10/7/2003	X				
10/14/2003	X	X			9:00 AM Continuous monitoring resumes after completion of pier reconstruction.
10/20/2003			X		
10/21/2003	X	X			
10/26/2003					Oct 26-27, 3.19 inches of rain in 24 hrs
10/29/2003	X	X			

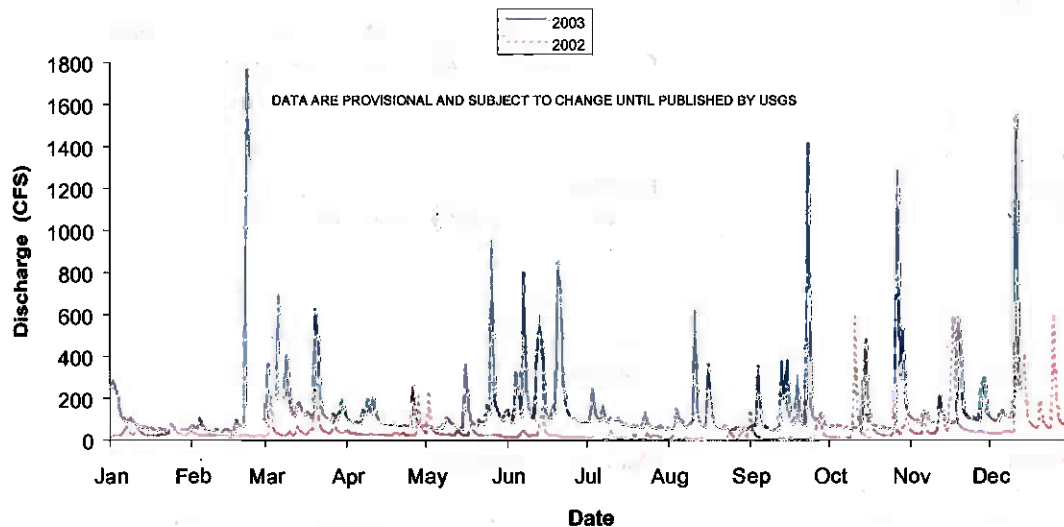
Table 1. Dates of 2003 water sample collection, DATAFLOW cruises, algal sample collection and other events and details.

2003 was one of the wettest years on record for Maryland and can be observed through precipitation records at BWI Airport (Table 2). This wet year was all the more unusual as it was preceded by an exceptional drought year in 2002. Comparison of water inflow for 2002 and 2003 to average flows highlights these disparities (Figure 2). In the Bush River, 2002 and 2003 water discharge records from the USGS Otter Point Creek Gauging station further illustrate the difference between these years (Figure 3). Further compounding 2003 high flows was a tidal surge and over three inches of rainfall from Hurricane Isabel on September 18, 2003 and a subsequent rain event several days later.

Station: Baltimore BWI		Total Rainfall For Month (inches):	Departure from Normal (inches)	Greatest in a 24Hr Period (inches)	ON Day(s) of Month
January	2003	2.59	-0.88	1.68	1-1
February	2003	6.7	3.68	2.55	21-22
March	2003	4.17	0.24	1.83	20-20
April	2003	2.4	-0.6	0.79	25-26
May	2003	6.81	2.92	1.96	16-16
June	2003	6.95	3.53	1.63	7-7
July	2003	5.56	1.71	1.84	2-3
August	2003	4.61	0.87	0.96	3-4
September	2003	7.47	3.49	2.4	22-23
October	2003	5.82	2.66	3.19	26-27
November	2003	4.86	1.74	1.5	19-19
December	2003	4.71	1.36	1.33	10-11

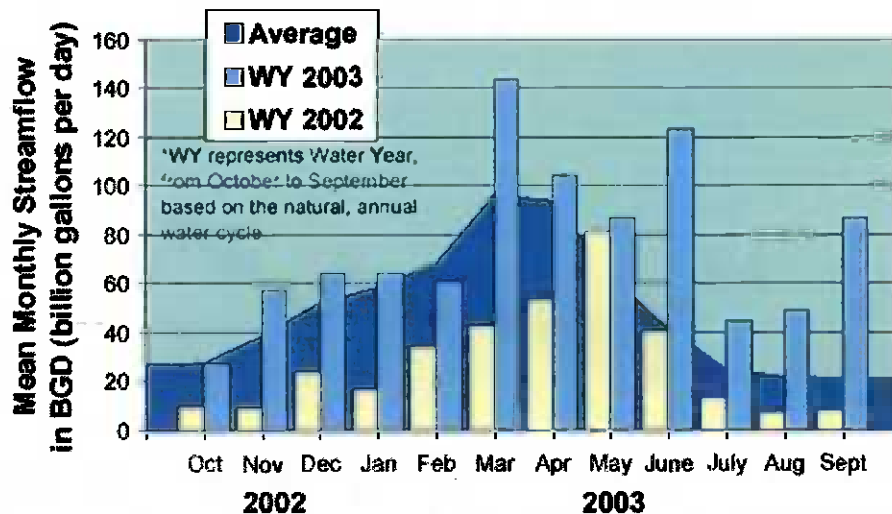
**Table 2.** Baltimore Washington International Airport Precipitation 2003.

#### **Otter Point Creek Daily Discharge 2003 Vs 2002**



**Figure 2.** Comparison of Daily Discharge 2002 and 2003. USGS Gage 01581757 at Otter Point Creek Near Edgewood, Md. (Provisional data subject to revision).

### Flow into the Chesapeake Bay Near Record High for Water Year 2003

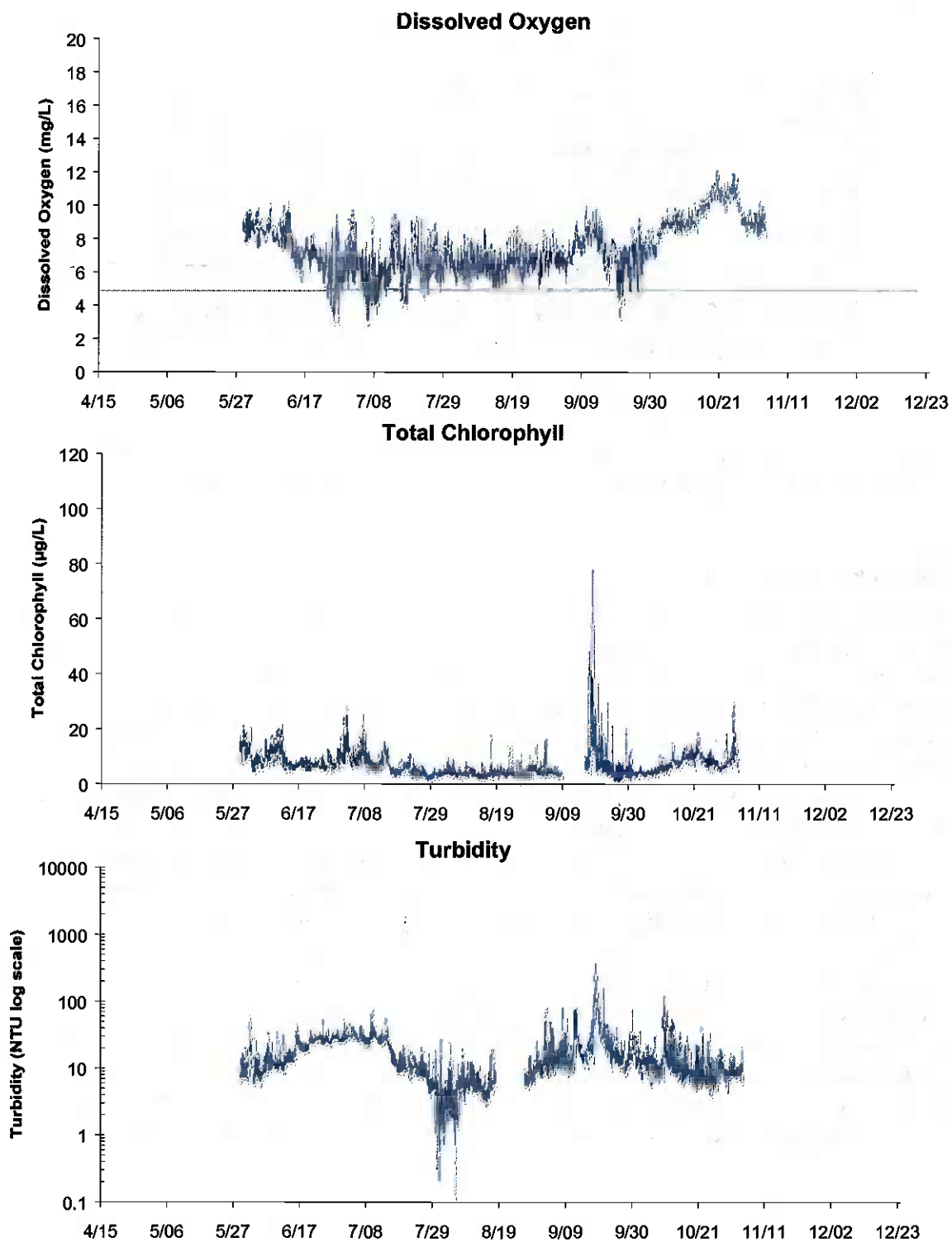


**Figure 3.** Mean Monthly Streamflow into Chesapeake Bay with monthly flow for water-years 2002 and 2003. (Data courtesy of United States Geological Survey).

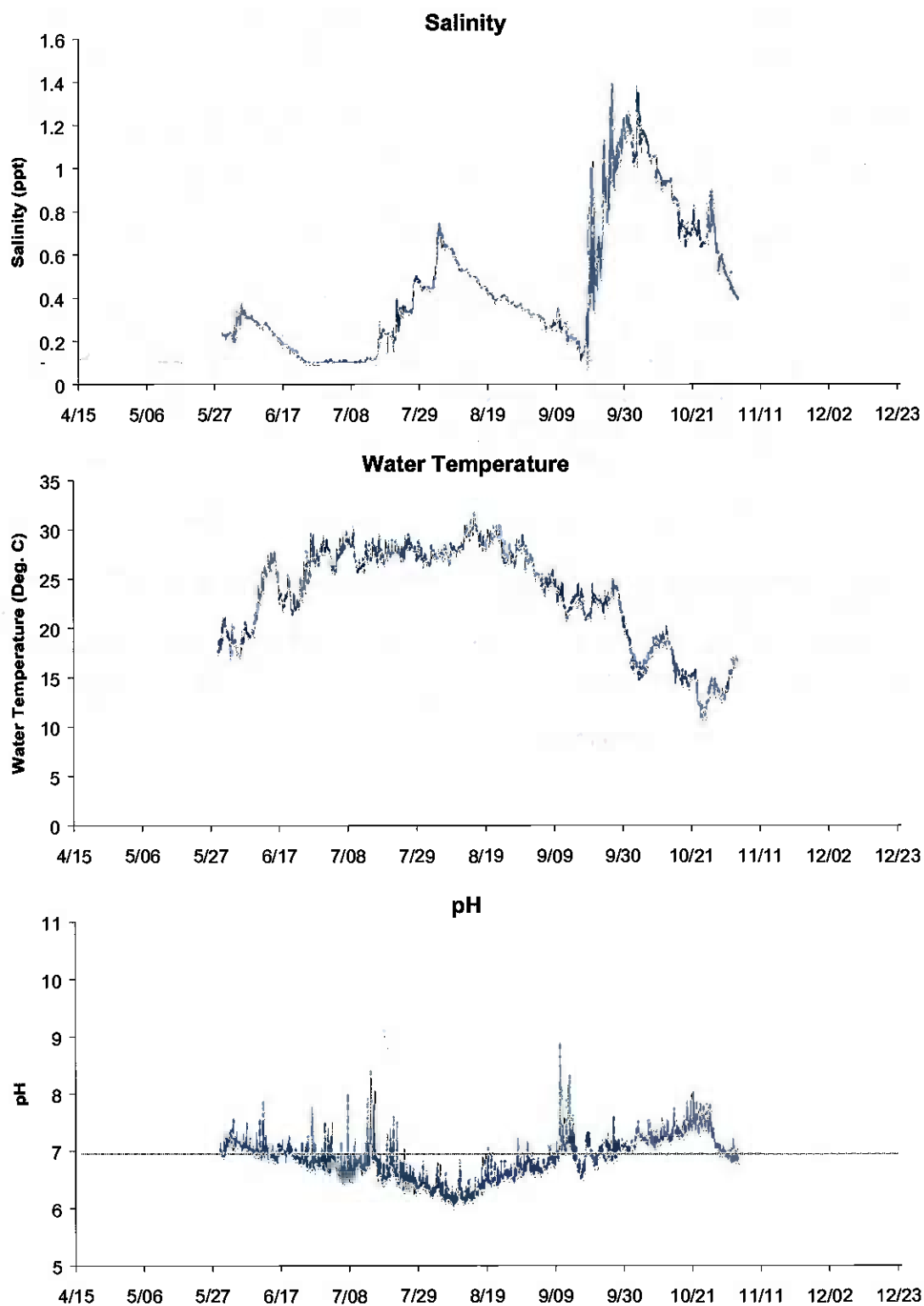
#### Continuous Monitoring

In 2003, the Lauderick Creek continuous monitoring site was deployed from May 29, 2003 to November 12, 2003 at one-meter below the water's surface and the Otter Point Creek site was deployed April 15, 2003 to December 23, 2003 at 0.3 meters from the bottom. Otter Point Creek equipment was temporarily removed from service on September 2, 2003 to allow for pier reconstruction and was redeployed on October 14, 2003. Charts of annual continuous monitoring data illustrate many interesting observations. Figure 4 shows some ephemeral effects of Hurricane Isabel (September 18, 2003) at Lauderick Creek. Immediately following the hurricane, short-term rises in turbidity were observed, followed by brief chlorophyll blooms and resultant dissolved oxygen sags. Increases in salinity of roughly one part per thousand were observed as a result of Isabel's tidal surge (Figure 5). Other continuous monitoring stations in Maryland tributaries experienced salinity increases of over 6 parts per thousand from the tidal surge. Following the hurricane, nitrate values appear to rise from previous lower summer levels (Table 4). Overall, turbidity values were at their low during the end of July and beginning of August in relation to periods of lower flow which can be observed in higher salinity levels (Figure 5) and USGS flow data at Otter Point Creek (Figure 3). For Lauderick Creek dissolved oxygen data, 3.92% of the 152,551 measurements fell below 5 mg/l, the level at which many organisms begin to exhibit signs of stress.





**Figure 4.** Lauderick Creek 2003 Dissolved Oxygen, Total Chlorophyll and Turbidity.

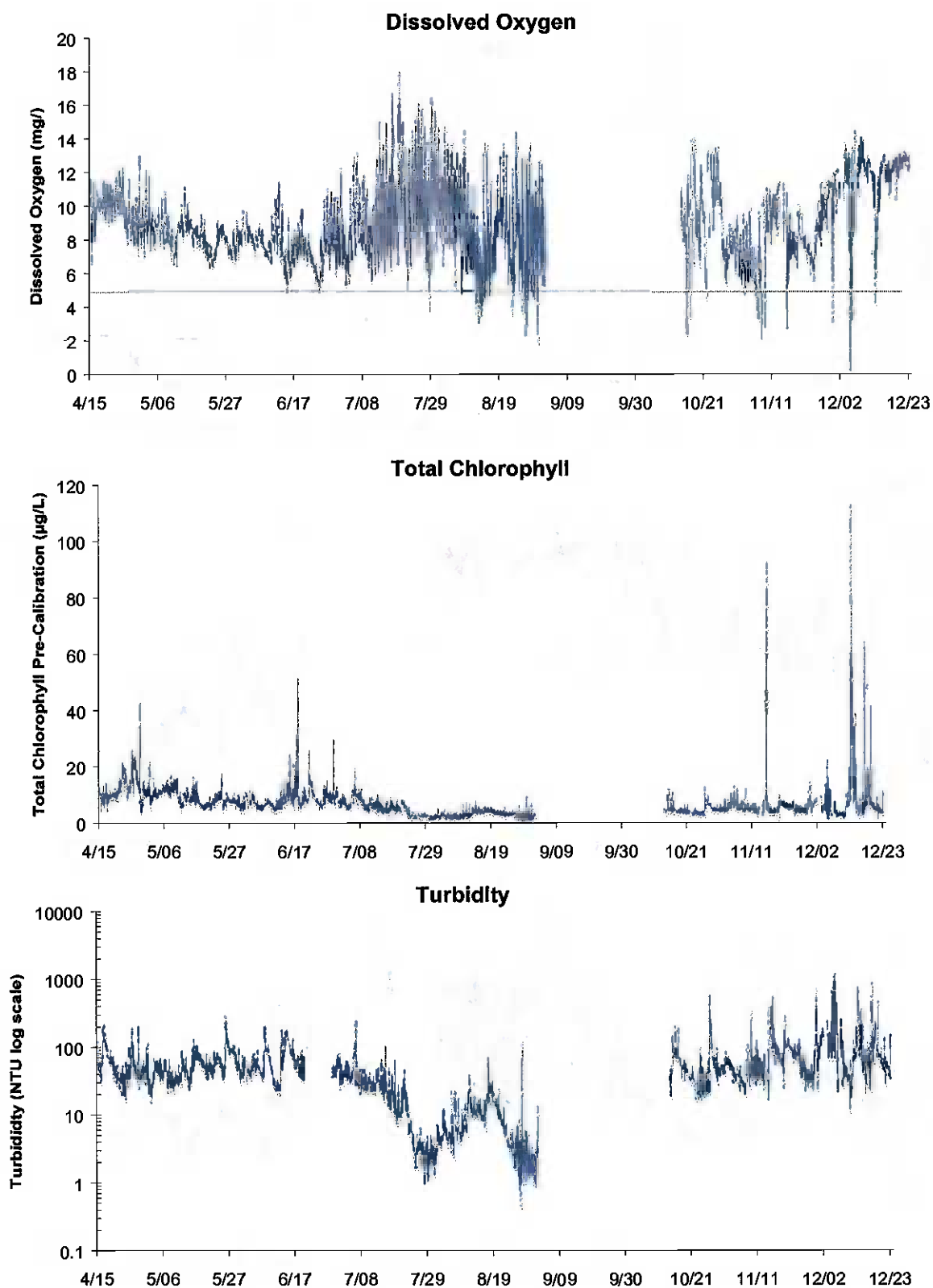


**Figure 5.** Lauderick Creek 2003 Salinity, Water Temperature and pH.

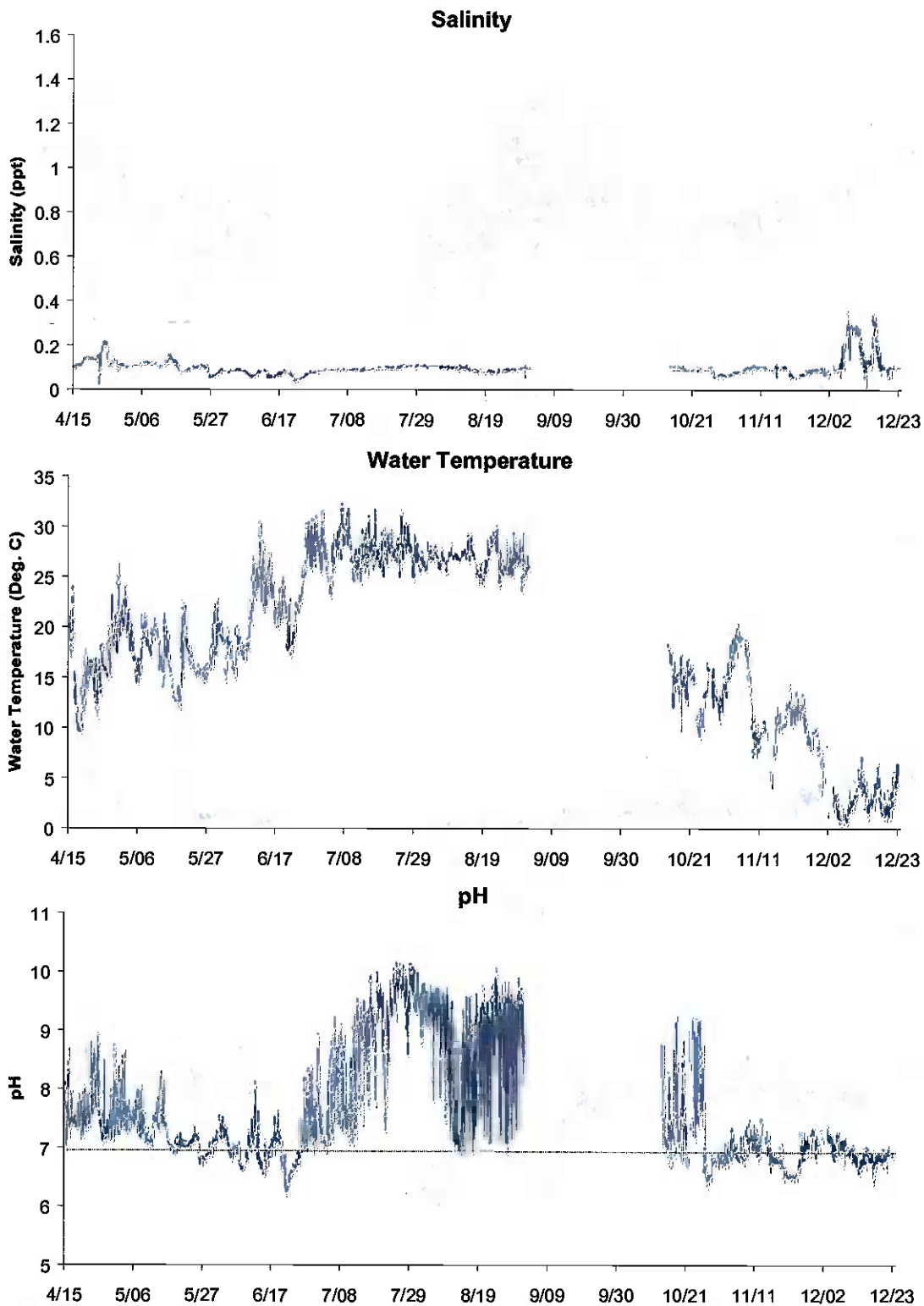
Due to its shallower depth, Otter Point Creek data (Figure 6) show that dissolved oxygen data exhibit greater daily fluctuations than Lauderick Creek. For the year, 2.25% of the 192,888 values were below 5 mg/l at the Otter Point Creek site. As anticipated, turbidity at the upriver site at Otter Point Creek (Figure 6) was an order of magnitude higher than the downriver Lauderick Creek (Figure 4) site. Chlorophyll levels for both creeks were lower than anticipated, mainly due to high turbidities that reduced light availability for algal growth. Unfortunately, the fluorometer on the YSI 6600 continuous monitors is unable to detect blue-green (*Microcystis*) algal concentrations which frequently occur in the Bush River. YSI, Inc. is currently working on the development of a fluorometry probe that better detects blue-green algae. Surrogate parameters, such as high pH values, could indicate the presence of a blue-green bloom. For instance, pH values of 9 to 10 observed during July and August at Otter Point Creek (Figure 7), were concurrent with *Microcystis* blooms. Chlorophyll measurements from the weekly calibration data exceeded the SAV habitat requirements of 15 ug/l, 3.17% of 19,291 observations at Otter Point Creek and 3.36% out of 14,539 observations at Lauderick Creek.

2003 Bush River continuous monitoring data are archived on the Eyes on the Bay website at:

[http://mddnr.chesapeakebay.net/newmontech/contmon/archivcd\\_results2.cfm?year=2003](http://mddnr.chesapeakebay.net/newmontech/contmon/archivcd_results2.cfm?year=2003) and can be further queried to produce data charts and data tables at varying time scales. Complete results on weekly nutrient, pigment, TSS, VSS, and Secchi depths for both continuous monitoring sites are located in Tables 3-6. Limits of detection for these parameters are outlined in Table 7. Ambient water quality parameter data, collected concurrently with nutrient and pigments, are located in Tables 8 and 9.



**Figure 6.** Otter Point Creek 2003 Dissolved Oxygen, Total Chlorophyll and Turbidity



**Figure 7.** Otter Point Creek 2003 Salinity, Water Temperature and pH.

Date	Sample Depth (m)	Chlorophyll a ( µg/l)	Pheophytin (µg/l)	Total Suspended Solids (mg/l)	Volatile Suspended Solids (mg)	Secchi Disk Depth (m)
29-May-03	1.0	7.102	2.056	17.0	4.5	
05-Jun-03	1.0	6.878	1.495	6.4	2.0	0.9
11-Jun-03	1.0	11.460	1.445	9.3	4.7	0.5
19-Jun-03	1.0	6.479	2.592	13.3	4.0	0.4
25-Jun-03	1.0	13.950	3.489	14.0	5.3	0.4
02-Jul-03	1.0	23.920	5.034	17.3	4.0	0.3
09-Jul-03	1.0	6.542	16.350	65.0	11.3	0.4
16-Jul-03	1.0	5.981	7.626	13.3	6.7	0.6
23-Jul-03	0.8	4.859	3.514	6.5	2.0	0.7
30-Jul-03	1.0	4.486	1.794	20.0	7.6	1.2
06-Aug-03	1.0	4.785	2.542	5.2	2.4	0.9
13-Aug-03	1.0	11.960	2.273	5.2	4.0	0.9
20-Aug-03	0.7	6.355	1.757	4.0	5.0	0.8
27-Aug-03	0.8	5.233	1.308	8.5	3.5	0.7
04-Sep-03	1.0	4.486	2.056	4.5	3.5	1.0
09-Sep-03	1.0	5.482	1.844	6.7	5.3	0.6
16-Sep-03	1.0	9.719	2.318	21.0	8.0	0.4
01-Oct-03	1.0	4.984	1.645	13.3	6.0	0.6
07-Oct-03	0.8	4.486	0.748	10.0	4.0	0.7
14-Oct-03	1.0	7.476	1.944	16.0	4.0	0.8
21-Oct-03	1.0	7.476	1.159	8.0	3.0	1.0
29-Oct-03	1.0	4.984	1.296	6.7	2.7	0.7

**Table 3.** Lauderick Creek 2003 Weekly Pigment, Suspended Solids and Secchi Disk values.

Date	Depth (m)	NH <sub>4</sub> (mg/l)	NO <sub>2</sub> (mg/l)	NO <sub>3</sub> (mg/l)	TDN (mg/l)	PN (mg/l)	PO <sub>4</sub> (mg/l)	PP (mg/l)	TDP (mg/l)	SiO <sub>2</sub> (mg/l)	PC (mg/l)
29-May-03	1.0	0.078	0.0092	0.5998	1.08	0.146	0.0086	0.0227	0.0322	2.76	1.34
05-Jun-03	1.0	0.072	0.0121	0.6019	1.12	0.175	0.0098	0.0212	0.0369	3.03	1.02
11-Jun-03	1.0	0.021	0.0077	0.4963	1.01	0.232	0.0036	0.0276	0.0255	3.23	1.30
19-Jun-03	1.0	0.066	0.0082	0.5758	1.19	0.206	0.0218	0.0269	0.0618	3.92	1.14
25-Jun-03	1.0	0.024	0.0114	0.5956	1.17	0.220	0.0161	0.0318	0.0514	2.85	1.56
02-Jul-03	1.0	0.068	0.0101	0.3219	0.88	0.240	0.0110	0.0344	0.0497	2.80	1.53
09-Jul-03	1.0	0.207	0.0095	0.2055	0.88	0.368	0.0385	0.0832	0.0811	1.83	3.19
16-Jul-03	1.0	0.220	0.0070	0.1210	0.78	0.143	0.0411	0.0218	0.0728	0.34	1.03
23-Jul-03	0.8	0.153	0.0035	0.0846	0.71	0.131	0.0288	0.0168	0.0527	0.51	0.92
30-Jul-03	1.0	0.114	0.0041	0.0290	0.59	0.110	0.0155	0.0149	0.0372	0.51	0.62
06-Aug-03	1.0	0.137	0.0019	0.0286	0.52	0.112	0.0168	0.0199	0.0463	0.64	0.67
13-Aug-03	1.0	0.014	0.0014	0.0112	0.53	0.195	0.0111	0.0225	0.0295	1.28	1.07
20-Aug-03	0.7	0.044	0.0017	0.0025	0.42	0.136	0.0068	0.0169	0.0324	1.77	0.71
27-Aug-03	0.8	0.144	0.0031	0.0195	0.56	0.133	0.0204	0.0183	0.0685	1.30	0.85
04-Sep-03	1.0	0.106	0.0024	0.0487	0.72	0.133	0.0343	0.0164	0.0387	0.58	0.78
09-Sep-03	1.0	0.073	0.0015	0.0065	0.70	0.145	0.0121	0.0176	0.0547	0.43	1.05
16-Sep-03	1.0	0.078	0.0031	0.0446	0.71	0.184	0.0049	0.0339	0.0275	0.63	1.44
01-Oct-03	1.0	0.036	0.0061	0.3549	0.74	0.138	0.0049	0.0230	0.0172	1.58	0.91
07-Oct-03	0.8	0.039	0.0050	0.3680	0.91	0.128	0.0047	0.0154	0.0176	1.41	0.84
14-Oct-03	1.0	0.015	0.0053	0.3287	0.72	0.206	0.0027	0.0272	0.0135	1.40	1.26
21-Oct-03	1.0	0.003	0.0071	0.3709	0.90	0.143	0.0020	0.0155	0.0233	1.77	0.81
29-Oct-03	1.0	0.117	0.0062	0.2828	0.75	0.136	0.0107	0.0166	0.0286	1.40	0.84

**Table 4.** Lauderick Creek 2003 Nutrient data: Ammonium (NH<sub>4</sub>), Nitrite (NO<sub>2</sub>), Nitrate (NO<sub>3</sub>), Total Dissolved Nitrogen (TDN), Particulate Nitrogen (PN), Phosphate (PO<sub>4</sub>), Particulate Phosphate (PP), Total Dissolved Nitrogen (TDP), Silicate (SiO<sub>4</sub>) and Particulate Carbon (PC).

Date	Sample Depth (m)	Chlorophyll a ( $\mu\text{g/l}$ )	Pheophytin ( $\mu\text{g/l}$ )	Total Suspended Solids (mg/l)	Volatile Suspended Solids (mg)	Secchi Disk Depth (m)
15-Apr-03	0.1	5.327	1.477	186.3	20.0	
23-Apr-03	0.1	22.430	0.000	24.0	6.0	
30-Apr-03	0.4	23.360	7.383	82.5	8.7	
08-May-03	0.7	21.490	7.289	82.5	13.7	
14-May-03	0.4	14.950	3.364	55.0	10.0	
21-May-03	0.5	7.476	2.990	55.0	7.5	
29-May-03	0.7	7.476	1.682	45.0	10.0	
04-Jun-03	0.4	14.950	1.794	50.0	12.0	0.1
11-Jun-03	0.3	11.210	0.000	19.0	7.0	0.3
18-Jun-03	0.7	9.719	1.794	21.0	6.0	0.3
25-Jun-03	0.4	3.738	0.449	33.0	9.0	0.2
02-Jul-03	0.7	11.960	2.691	24.7	5.3	0.4
09-Jul-03	0.1	5.607	2.243	41.2	10.0	0.2
16-Jul-03	0.7	8.971	2.019	8.7	4.7	0.3
23-Jul-03	0.2	3.489	0.698	12.0	2.7	0.5
30-Jul-03	0.8	3.289	0.000	2.4	3.2	1.1
30-Jul-03	0.8	2.691	0.449	2.4	2.8	
06-Aug-03	0.2	4.859	1.159	12.5	3.5	0.5
13-Aug-03	0.5	8.473	1.296	9.3	4.0	0.4
20-Aug-03	0.2	4.486	0.050	8.0	6.0	0.5
27-Aug-03	0.5	2.990	1.196	2.4	3.0	0.8
27-Aug-03	0.5	1.495	0.860	2.4	3.0	
02-Sep-03	0.6	59.430	16.190	21.5	8.5	0.9
14-Oct-03	0.4	6.728	2.691	24.0	6.0	0.2
21-Oct-03	0.7	5.981	2.392	29.0	6.0	0.3
29-Oct-03	0.5			48.0	7.0	0.2
29-Oct-03	0.5	4.486	0.000			

**Table 5.** Otter Point 2003 Weekly Pigment, Suspended Solids and Secchi Disk values.  
N.B. On the dates 30-Jul-03 and 27-Aug-03 a second replicate sample was taken.



Date	Depth (m)	NH <sub>4</sub> (mg/l)	NO <sub>2</sub> (mg/l)	NO <sub>3</sub> (mg/l)	TDN (mg/l)	PN (mg/l)	PO <sub>4</sub> (mg/l)	PP (mg/l)	TDP (mg/l)	SiO <sub>2</sub> (mg/l)	PC (mg/l)
15-Apr-03	0.1	0.024	0.0124	1.4076	1.83	1.270	0.0076	0.1838	0.0317	3.36	9.44
23-Apr-03	0.1	0.005	0.0107	1.0393	1.52	0.393	0.0028	0.0515	0.0176	3.16	2.76
30-Apr-03	0.4	0.018	0.0099	0.8901	1.23	0.565	0.0033	0.0981	0.0171	3.41	3.94
08-May-03	0.7	0.019	0.0139	0.8681	1.18	0.584	0.0033	0.1012	0.0151	3.65	4.12
14-May-03	0.4	0.031	0.0127	0.9033	1.36	0.420	0.0016	0.0883	0.0183	3.73	3.00
21-May-03	0.5	0.126	0.0177	1.0423	1.59	0.258	0.0036	0.0693	0.0248	4.60	2.33
29-May-03	0.7	0.123	0.0140	0.7910	1.38	0.269	0.0055	0.0673	0.0286	4.22	2.42
04-Jun-03	0.4	0.084	0.0211	1.1489	1.70	0.345	0.0051	0.0501	0.0194	5.03	2.54
11-Jun-03	0.3	0.044	0.0125	1.1175	1.61	0.207	0.0046	0.0307	0.0205	5.48	1.35
18-Jun-03	0.7	0.075	0.0158	1.1042	1.58	0.321	0.0045	0.0429	0.0277	5.10	1.72
25-Jun-03	0.4	0.100	0.0115	0.9885	1.53	0.141	0.0064	0.0406	0.0247	4.81	1.35
02-Jul-03	0.7	0.012	0.0175	1.2025	1.59	0.291	0.0076	0.0400	0.0238	5.14	1.81
09-Jul-03	0.1	0.065	0.0180	0.8260	1.23	0.587	0.0106	0.0602	0.0206	4.03	3.15
16-Jul-03	0.7	0.060	0.0204	1.0696	1.47	0.342	0.0108	0.0435	0.0216	4.26	1.84
23-Jul-03	0.2	0.030	0.0272	0.8178	1.18	0.119	0.0087	0.0191	0.0213	3.78	0.80
30-Jul-03	0.8	0.003	0.0159	0.5451	0.99	0.103	0.0098	0.0129	0.0155	2.79	0.54
30-Jul-03	0.8	0.006	0.0160	0.5310	0.97		0.0030		0.0221		
06-Aug-03	0.2	0.023	0.0213	0.6107	0.99	0.091	0.0046	0.0182	0.0201	4.97	0.96
13-Aug-03	0.5	0.057	0.0352	0.4748	0.93	0.104	0.0047	0.0137	0.0192	2.25	1.05
20-Aug-03	0.2	0.019	0.0112	0.2038	0.63	0.055	0.0037	0.0132	0.0169	0.90	0.51
27-Aug-03	0.5	0.023	0.0075	0.1705	0.86	0.080	0.0051	0.0085	0.0136	0.45	0.51
27-Aug-03	0.5	0.032	0.0082	0.1758	0.69		0.0027		0.0567		
02-Sep-03	0.6	0.035	0.0070	0.3060		0.690	0.0045	0.0536		0.50	4.54
14-Oct-03	0.4	0.016	0.0083	1.0717	1.33	0.153	0.0035	0.0287	0.0116	1.19	1.04
21-Oct-03	0.7	0.011	0.0066	0.9734	1.52	0.133	0.0027	0.0342	0.0189	1.32	1.25
29-Oct-03	0.5	0.046	0.0063	0.5417	1.06	0.125	0.0055	0.0267	0.0266	2.78	1.17

**Table 6.** Otter Point Creek 2003 Ammonium (NH<sub>4</sub>), Nitrite (NO<sub>2</sub>), Nitrate (NO<sub>3</sub>), Total Dissolved Nitrogen (TDN), Particulate Nitrogen (PN), Phosphate (PO<sub>4</sub>), Particulate Phosphate (PP), Total Dissolved Nitrogen (TDP), Silicate (SiO<sub>4</sub>) and Particulate Carbon (PC). N.B. On the dates 30-Jul-03 and 27-Aug-03 a second replicate sample was taken.

**Table 7.** Limits of detection, the lowest concentration of an analyte that the analytical procedure can reliably detect, have been established for all parameters routinely measured by Nutrient Analytical Services. The limit of detection is 3 times the standard deviation of a minimum of 7 replicates of a single low concentration sample.

Minimum limits of detection of CBL, October/November 1987, March 1994 a			
	MEAN CONC.	STANDARD DEVIATION	DETECTION LIMIT
NUTRIENT	(mg/l)	(mg/l)	(mg/l)
Ammonium	0.007	0.001	0.003
Nitrite	0.0002	0.00005	0.0002
Nitrite + Nitrate	0.0011	0.00023	0.0007
Phosphate	0.0027	0.00025	0.0007
Dissolved Organic Carbon	3.58	0.05	0.15
Total Suspended Solids	13.4	0.8	2.4
Particulate Phosphorus	0.0187	0.0008	0.0024
Particulate Inorganic Phosphorus	0.0027	0.0002	0.0006
Total Dissolved Nitrogen	0.39	0.0096	0.02
Total Dissolved Phosphorus	0.0057	0.0005	0.0015
Silicate	0.25	0.003	0.01
Particulate Nitrogen	0.317	0.0041	0.0123
Particulate Carbon	2.26	0.0253	0.0759
Particulate Biogenic Silica	0.163	0.003	0.009
Sediment C (10 mg)	0.02183	0.044	0.0013
Sediment N (10 mg)	0.00195	0.003	0.000084
Sediment P (34.8 mg)	0.000304	0.003	0.000087
FRESHWATER DETECTION LIMITS (1991)			
Total Volatile Solids	3.5	0.3	0.9
Hardness	41.8	2.1	6.3
Chloride	5.84	0.08	0.23
Sulfate	4.9	0.03	0.09
Carbonate Alkalinity	1.46	4.38	
Chlorophyll a	4	0.68	2.00 (µg/l)
a Results based on a minimum of seven replicates collected from one cubitainer and analyzed randomly on a typical day of analyses.			
<a href="http://www.cbl.umces.edu/nasl/">http://www.cbl.umces.edu/nasl/</a>			

Date	Depth (m)	specific Conductance ( $\mu\text{S}/\text{cm}$ )	D.O. (mg/l)	pH	Salinity (psu)	Water Temperature ( $^{\circ}\text{C}$ )
29-May-03	1.0	485	8.4	7.03	0.00	17.2
05-Jun-03	1.0	641	8.1	6.98	0.00	17.0
11-Jun-03	1.0	563	8.8	7.14	0.00	23.4
19-Jun-03	1.0	301	7.2	7.02	0.00	23.0
25-Jun-03	1.0	203	7.5	7.16	0.00	26.3
02-Jul-03	1.0	217	7.4	7.11	0.00	27.7
09-Jul-03	1.0	222	4.4	6.58	0.00	28.4
16-Jul-03	1.0	308	6.4	6.91	0.00	27.4
23-Jul-03	0.8	700	4.9	6.45	0.02	27.8
30-Jul-03	1.0	918	6.9	6.42	0.14	27.2
06-Aug-03	1.0	1287	5.4	6.16	0.34	27.1
13-Aug-03	1.0	1036	6.6	6.34	0.20	29.6
20-Aug-03	0.7	857	6.6	6.45	0.10	28.5
27-Aug-03	0.8	741	6.1	6.62	0.04	27.1
04-Sep-03	1.0	603	6.5	6.63	0.00	25.1
09-Sep-03	1.0	608	7.3	6.99	0.00	24.2
16-Sep-03	1.0	326	7.2	6.69	0.00	22.6
01-Oct-03	1.0	2421	7.2	7.07	0.96	19.5
07-Oct-03	0.8	2169	9.0	7.16	0.82	15.9
14-Oct-03	1.0	1856	8.9	7.16	0.65	18.2
21-Oct-03	1.0	1444	10.8	7.43	0.42	14.9
29-Oct-03	1.0	1063	8.9	7.09	0.22	13.6

**Table 8.** Lauderick Creek 2003 HydroLab values at time of pigment and nutrient samples. Depth (m), specific Conductance ( $\mu\text{S}/\text{cm}$ ), Dissolved Oxygen (mg/l), pH, Salinity (psu) and Water Temperature ( $^{\circ}\text{C}$ ).

Date	Depth (m)	specific Conductance ( $\mu$ S/cm)	D.O. (mg/l)	pH	Salinity (psu)	Water Temperature (°C)
15-Apr-03	0.1	215	11.1	7.73	0.00	19.6
23-Apr-03	0.1	319	11.5	8.07	0.00	14.4
30-Apr-03	0.4	217	8.9	7.39	0.00	18.9
08-May-03	0.7	254	9.5	7.47	0.00	19.8
14-May-03	0.4	317	9.1	7.46	0.00	15.6
21-May-03	0.5	189	7.1	7.05	0.00	18.3
29-May-03	0.7	137	7.0	6.87	0.00	16.3
04-Jun-03	0.4	170	8.1	7.09	0.00	16.0
11-Jun-03	0.3	153	7.8	7.02	0.00	22.8
18-Jun-03	0.7	147	8.4	7.3	0.00	22.4
25-Jun-03	0.4	134	6.0	6.83	0.00	22.9
02-Jul-03	0.7	185	8.6	7.54	0.00	27.7
09-Jul-03	0.1	189	8.3	7.92	0.00	29.3
16-Jul-03	0.7	191	7.6	7.95	0.00	27.0
23-Jul-03	0.2	203	9.1	9.12	0.00	27.0
30-Jul-03	0.8	216	10.7	9.65	0.00	26.5
30-Jul-03	0.8	216	10.7	9.65	0.00	26.5
06-Aug-03	0.2	203	8.7	9.29	0.00	25.6
13-Aug-03	0.5	183	6.9	8.14	0.00	27.5
20-Aug-03	0.2	164	9.7	9.25	0.00	25.3
27-Aug-03	0.5	185	5.2	8.29	0.00	25.4
27-Aug-03	0.5	185	5.2	8.29	0.00	25.4
02-Sep-03	0.6	196	6.8	8.77	0.00	26.0
14-Oct-03	0.4	215	8.7	7.02	0.00	17.6
21-Oct-03	0.7	175	9.5	7.26	0.00	15.0
29-Oct-03	0.5	128	7.2	6.72	0.00	12.7

**Table 9.** Otter Point Creek 2003 HydroLab values at time of pigment and nutrient samples. Depth (m), specific Conductance ( $\mu$ S/cm), Dissolved Oxygen (mg/l), pH, Salinity (psu) and Water Temperature (°C).

## **Water Quality Mapping**

Bush River water quality mapping data were collected monthly, May through October 2003. Water quality mapping collects surface data every four seconds aboard a moving boat, creating thousands of data points in a daily cruise, and allows for the creation of highly detailed spatial maps of water quality. More information for this technology can be found at <http://mddnr.chesapeakebay.net/sim/index.cfm>. Data for dissolved oxygen, turbidity, chlorophyll, water temperature, and salinity were interpolated into spatially continuous surface maps (Figures 8-13) using the inverse distance weighted method. Data were quality assured and controlled but not standardized for time-of-day influences before interpolation. Approximately eight nutrient and calibration samples were collected during each cruise and analyzed at UMCES Chesapeake Biological Laboratory.

Overall results show that surface dissolved oxygen levels were mostly above 5 mg/l during collection, with areas of 5 – 7.5 mg/l occurring May through September. Temporal standardization of water quality mapping data with the continuous monitoring data could indicate that portions of these areas could deviate below 5 mg/l during early morning hours. Due to high water flows and runoff during 2003, turbidities were high throughout the river, May through September, with highest values observed upriver. High turbidities accounted for low light availability in the water column, restricting chlorophyll values to less than 20 ug/l throughout the tributary during the sampling period. Water quality mapping employs the same YSI 6600 fluorometer that is used in continuous monitoring and is therefore unable to detect blooms of blue-green algae. Maryland DNR is currently investigating new technologies to help us better monitor these blooms in the future. Water quality mapping data can be obtained through Eyes on the Bay at: [http://mddnr.chesapeakebay.net/sim/dataflow\\_data.cfm](http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm). A more complete analysis of the data will be possible when compared with the second year of data from 2004.

## **Conclusion**

Shallow water monitoring, consisting of temporally intensive continuous monitoring and spatially intensive water quality mapping, provides a critical function for assessing the health of Maryland's tidal waters in areas historically lacking in monitoring information. Not only will this information be used for characterizing the health of shallow water habitats, but its objectives are to: 1) assess the newly developed Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow and open water habitats, 2) determine attainment or non-attainment of shallow water and open water habitats for their designated uses, 3) provide spatially and temporally intensive data in shallow water habitats to improve water quality mapping interpolations, 4) assess SAV habitats and identify potential SAV restoration sites, 5) provide information to better understand ecosystem processes and the impact of extreme events (e.g. hurricanes, high flows) in shallow water and open water environments, and 6) provide information for calibrating the Bay Eutrophication and Watershed Model.

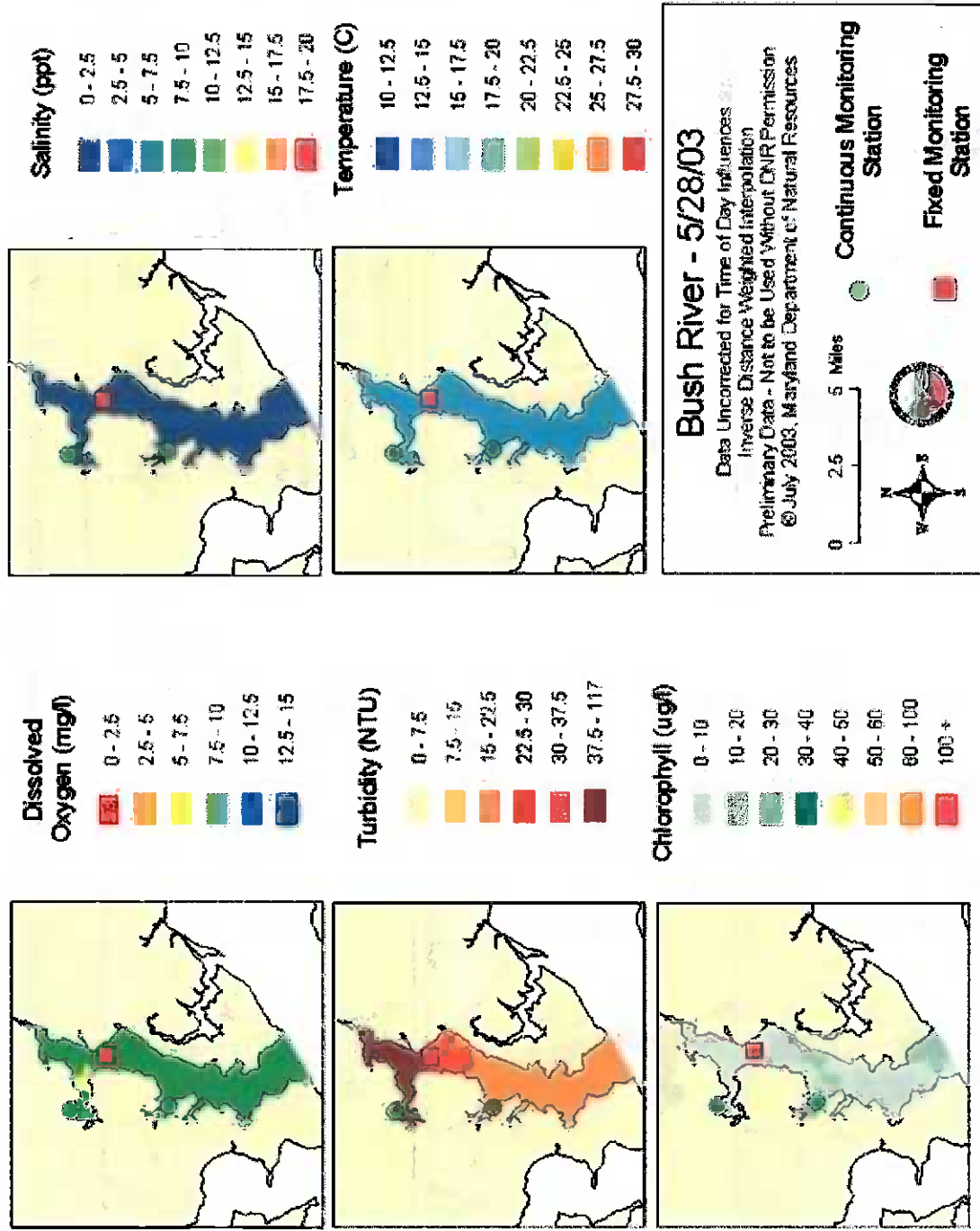


Figure 8. Bush River Water Quality Mapping from May 28, 2004.

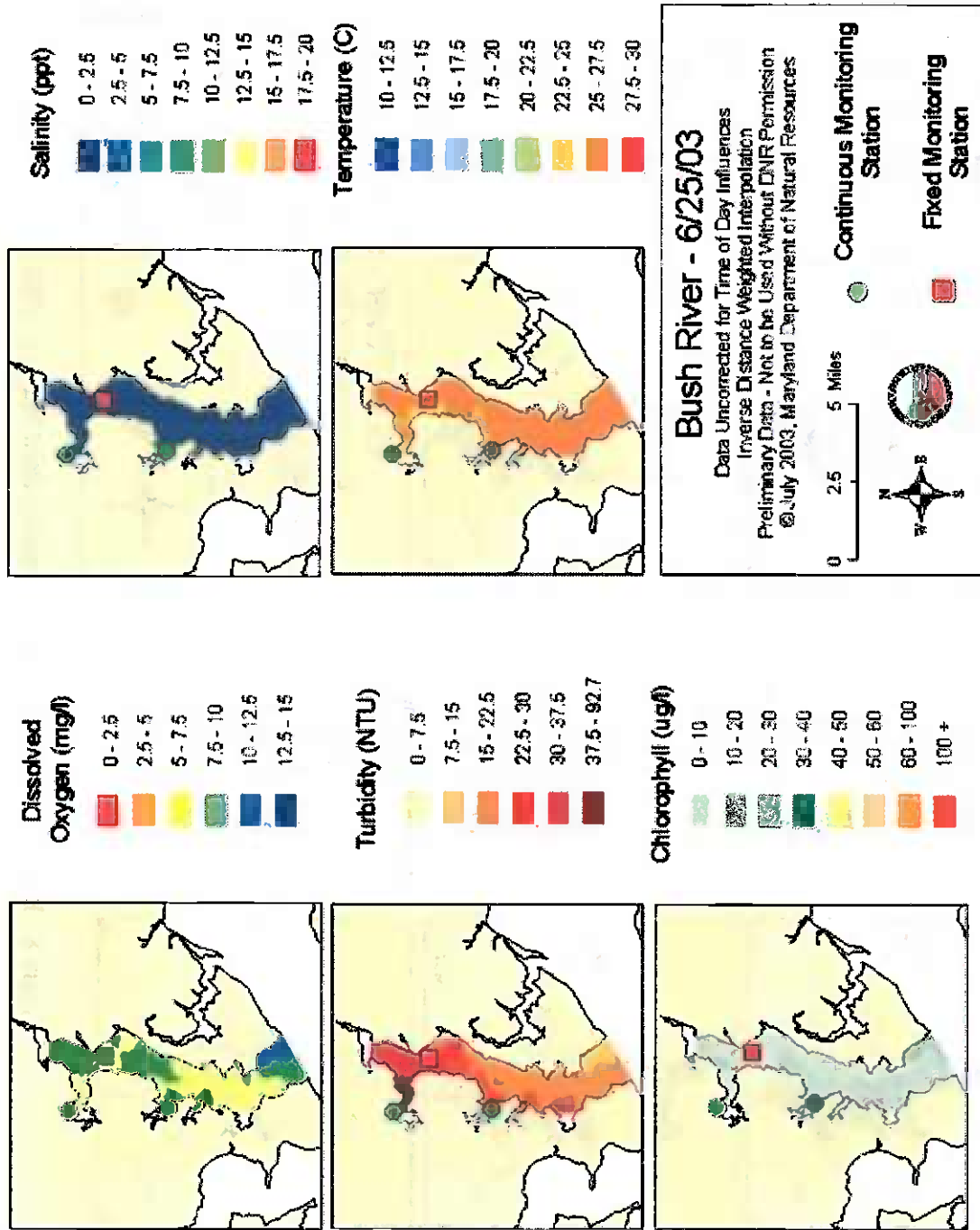


Figure 9. Bush River Water Quality Mapping from June 25, 2004.



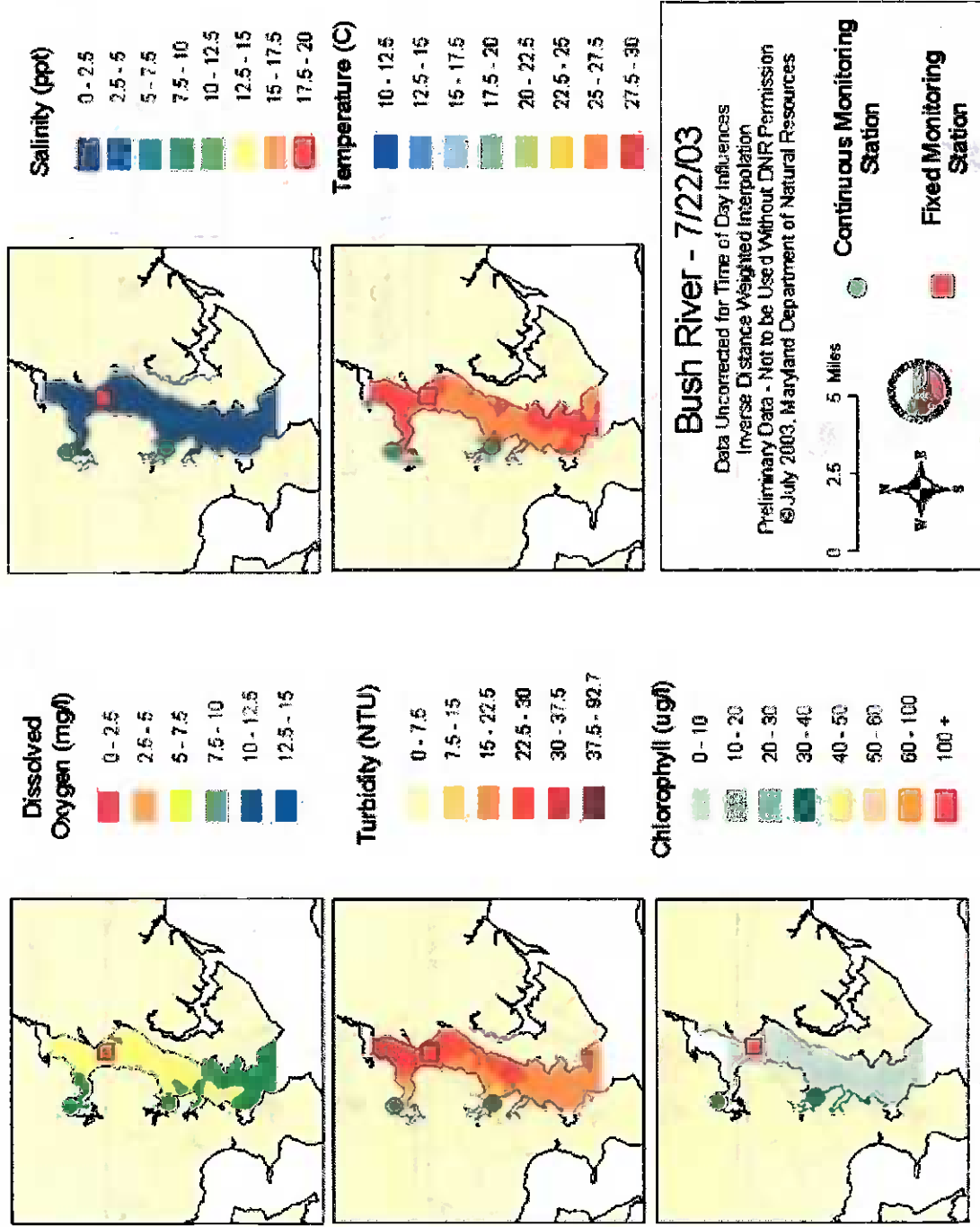


Figure 10. Bush River Water Quality Mapping from July 22, 2004.



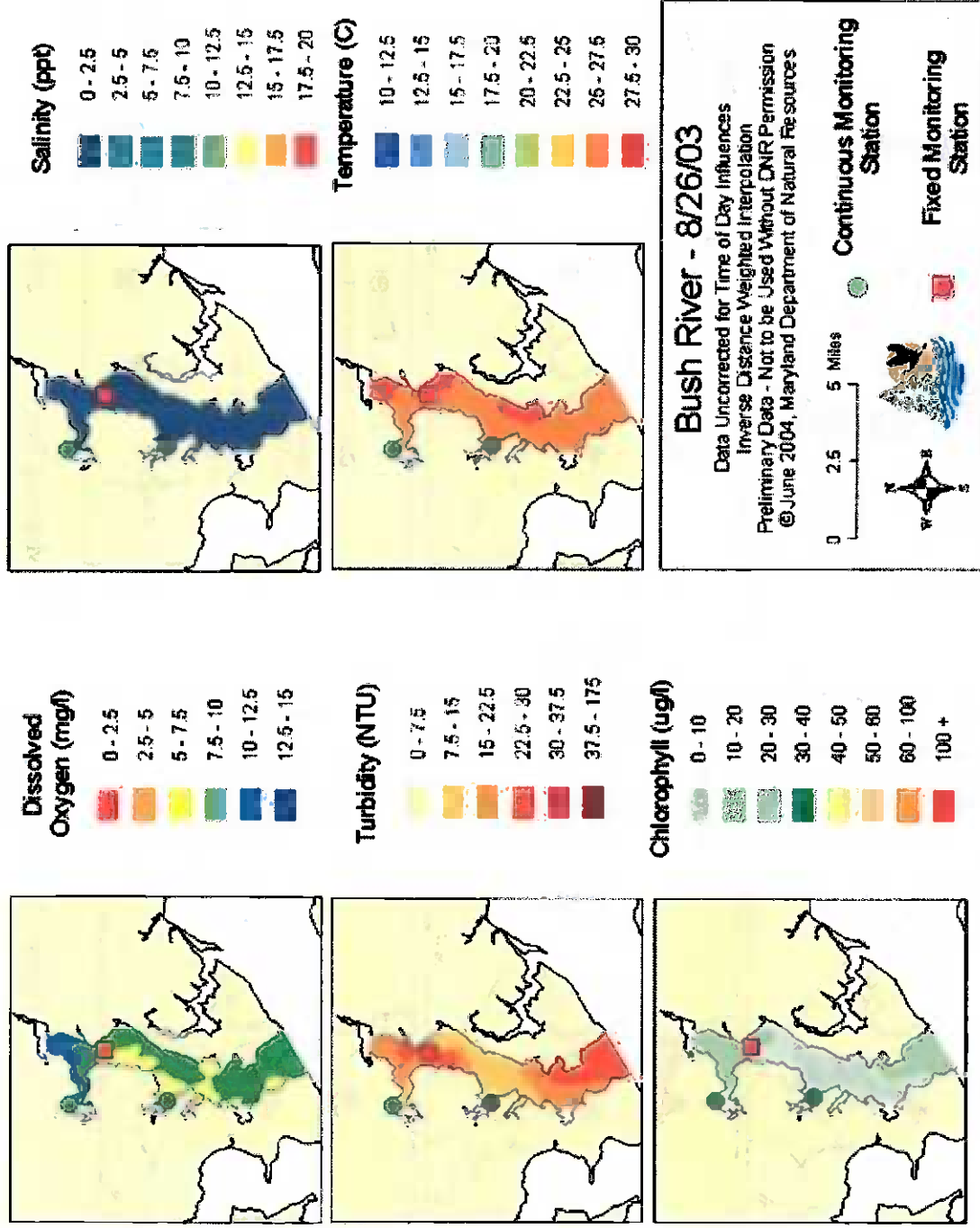


Figure 11. Bush River Water Quality Mapping from August 26, 2004.

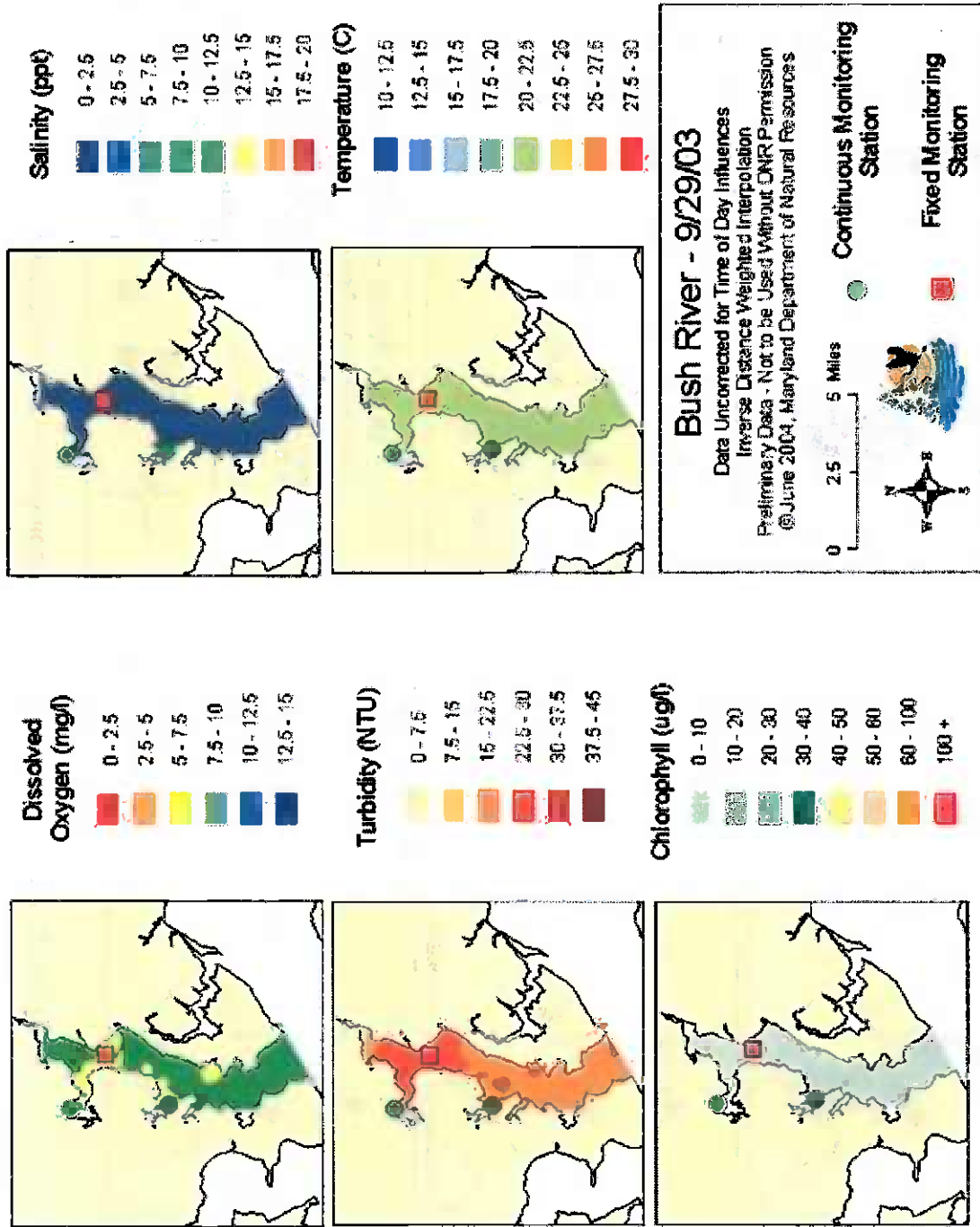


Figure 12. Bush River Water Quality Mapping from September 29, 2004.

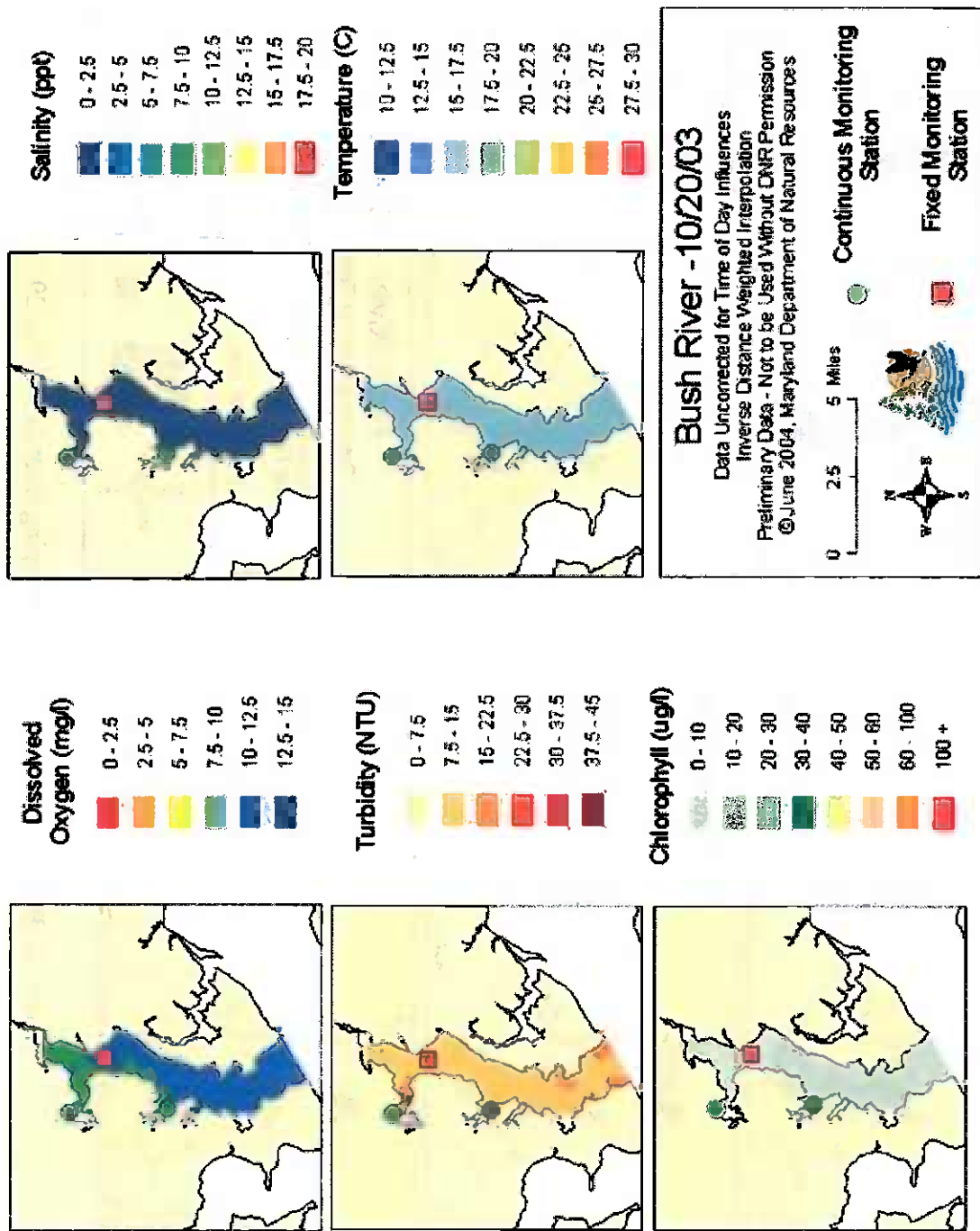


Figure 13. Bush River Water Quality Mapping from October 20, 2004.



**Robert L. Ehrlich, Jr.**  
*Governor*

**C. Ronald Franks**  
*Secretary*

**Michael S. Steele**  
*Lt. Governor*

**W.P. Jensen**  
*Deputy Secretary*

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# **Quality Assurance Project Plan**

**for the  
Maryland Department of Natural Resources  
Chesapeake Bay  
Shallow Water Quality Monitoring Program  
for the period July 1, 2004 - June 30, 2005**

May 27, 2004

# **Quality Assurance Project Plan for the Maryland Department of Natural Resources Chesapeake Bay Shallow Water Quality Monitoring Program**

Prepared by:

Bruce Michael, Beth Ebersole, Mark Trice, and Christopher Heyer  
Resource Assessment Service/Tidewater Ecosystem Assessment  
Maryland Department of Natural Resources  
Tawes Building, D-2  
580 Taylor Avenue  
Annapolis, MD 21401

Website Address:

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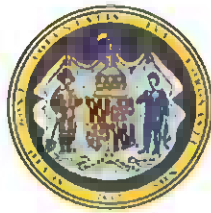
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Robert L. Ehrlich, Jr., Governor

Michael S. Steele, Lt. Governor



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**Quality Assurance Project Plan  
for the  
Maryland Department of Natural Resources  
Chesapeake Bay  
Shallow Water Quality Monitoring Program  
for the period July 1, 2004 - June 30, 2005**

May 27, 2004

---

Bruce Michael, Director, Principal Investigator and Quality Assurance Officer  
Maryland Department of Natural Resources

---

Rich Batiuk, Associate Director for Science/Quality Assurance Officer  
Chesapeake Bay Program Office  
U.S. Environmental Protection Agency

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## ACRONYMS AND ABBREVIATIONS

AA	- Autoanalyzer
AMQAW	- Analytical Methods and Quality Assurance Workgroup (a workgroup of the Chesapeake Bay Program's Monitoring Subcommittee)
C	- Carbon
CBP	- EPA's Chesapeake Bay Program
CBPO	- EPA's Chesapeake Bay Program Office
CBL	- University of Maryland's Chesapeake Biological Laboratory
cm	- Centimeter
CMC	- Chlorophyll Measurement Computer
CSSP	- Coordinated Split Sample Program
d	- Day
DHMH	- Maryland Department of Health and Mental Hygiene
DI	- De-Ionized
DNR	- Maryland Department of Natural Resources
DO	- Dissolved Oxygen
DOC	- Dissolved Organic Carbon
EPA	- U.S. Environmental Protection Agency
g	- Gram
h	- Hour
L	- Liter
m	- Meter
MDE	- Maryland Department of the Environment
min.	- Minute
mg	- Milligram
ml or mL	- Milliliter
mm	- Millimeter
N	- Nitrogen
NIST	- National Institute of Science and Technology
nm	- Nanometer
no.	- Number
NO <sub>2</sub>	- Nitrite
NO <sub>23</sub>	- Nitrate + Nitrite
NO <sub>3</sub>	- Nitrate
OD	- Optical Density
P	- Phosphorus
PAR	- Photosynthetic Active Radiation
PC	- Particulate Carbon OR
PC	- Personal Computer
PIP	- Particulate Inorganic Phosphorus
PN	- Particulate Nitrogen
PO <sub>4</sub>	- Phosphate
PP	- Particulate Phosphorus
ppt	- Parts Per Thousand
QA	- Quality Assurance
QAO	- Quality Assurance Officer (Unless Otherwise Noted, This Refers To The DNR QAO)
QAPP	- Quality Assurance Project Plan

QC	- Quality Control
R/V	- Research Vessel
SAS	- Statistical Analysis System
SAV	- Submerged Aquatic Vegetation
Si	- Silicon
SMCRP	- St. Mary's College River Project
TDN	- Total Dissolved Nitrogen
TDP	- Total Dissolved Phosphorus
TMDL	- Total Maximum Daily Load
trib	- Bay Tributary
TSS	- Total Suspended Solids
USDI	- U.S. Department of the Interior
USGS	- U.S. Geological Survey
°C	- degrees Celsius

## **PREFACE**

This document is intended to describe in detail the activities conducted under the Shallow Water Monitoring Program of the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program. This program includes water quality mapping and continuous monitoring in the tidal tributaries of Maryland's Chesapeake Bay. This program is funded through the Maryland Department of Natural Resources, the U.S. Environmental Protection Agency and the National Oceanographic Atmospheric Administration.

## LIST OF PREPARERS

### Editors:

**Bruce Michael**, Director, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Elizabeth L. Ebersole**, Environmental Research Statistician, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Mark Trice**, Environmental Research Statistician, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Christopher Heyer**, Environmental Research Statistician, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

### Contributors:

**Sally Bowen**, Program Chief, Monitoring Field Office, Monitoring and Non-Tidal Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 1919 Lincoln Drive, Annapolis, Maryland 21401.

**Asoka Katamuluwa**, Chief, Division of Environmental Chemistry, Maryland Department of Health and Mental Hygiene, Laboratories Administration, Division of Environmental Chemistry, 201 W. Preston Street, Baltimore, Maryland, 21203-2355.

**Bill Romano**, Environmental Research Statistician, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Chris Trumbauer**, Natural Resources Biologist, Monitoring and Non-Tidal Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 1919 Lincoln Drive, Annapolis, Maryland 21401.

**John Zimmerelli**, Natural Resources Biologist, Monitoring and Non-Tidal Assessment, Resource Assessment Service, Maryland Department of Natural Resources, Field Office, 1919 Lincoln Drive, Annapolis, Maryland 21401.

**Carl Zimmerman**, Chesapeake Biological Laboratory, University of Maryland, Center for Environmental Science, Solomons, Maryland, 20688-0038.

## DISTRIBUTION LIST

**Rich Batiuk**, Associate Director for Science/Quality Assurance Officer, Chesapeake Bay Program Office, U.S. Environmental Protection Agency, 410 Severn Avenue, Suite 109, Annapolis, MD 21403.

**Mary Ellen Ley**, Quality Assurance Coordinator, US Geological Survey/Chesapeake Bay Program Office, 410 Severn Avenue, Suite 109, Annapolis, MD 21403.

**Bruce Michael**, Director, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Elizabeth L. Ebersole**, Environmental Research Statistician, Tidewater Ecosystem Assessment, Resource-Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Christopher Heyer**, Environmental Research Statistician, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Mark Trice**, Environmental Research Statistician, Tidewater Ecosystem Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

**Carole Towle**, Director, Research Reserve Program, Coastal Zone Management, Maryland Department of Natural Resources, 580 Taylor Avenue, D-2, Annapolis, Maryland 21401.

This Quality Assurance Project Plan is also available on-line on the Maryland Department of Natural Resources (DNR) Eyes on the Bay web site: <http://www.eyesonthebay.net> and the DNR Bay Monitoring web site: <http://www.dnr.state.md.us/bay/monitoring/index.html>

## **1. INTRODUCTION AND PROJECT DESCRIPTION**

### **1.1 Background**

The Monitoring and Analysis Subcommittee's Tidal Monitoring and Analysis Workgroup (TMAW) has undertaken the role of redesigning the Tidal Monitoring Network. The new Tidal Monitoring Network focuses on meeting the Water Quality Protection and Restoration goals and objectives of the new Chesapeake 2000 Agreement. Water quality monitoring information will be used to define the nutrient and sediment conditions necessary to protect living resources (water quality to support crabs, oysters, and fish) and vital habitats (water quality to support submerged aquatic vegetation - SAV), and develop and assess water quality criteria with the goal of removing the Bay and its tidal rivers from the list of impaired waters. Water quality information also supports refinement, calibration and validation of the Chesapeake Bay Water Quality Model.

As part of the new Tidal Monitoring Network, Maryland Department of Natural Resources (DNR) and its federal, state and local partners are working together to implement a comprehensive and coordinated monitoring program to assess the Bay's shallow water habitats required by the development of the new water quality criteria. Currently, sparse water quality data is collected in shallow portions of Chesapeake Bay and its tributaries. This presents a major data gap in light of the new Designated Use Areas and Water Quality Criteria.

Water quality and habitat measurements will be made using water quality mapping technology and fixed continuous monitors to provide characterization of shallow water habitats that are key to living resources. Water quality mapping has been piloted by the states of Maryland and Virginia and academic researchers and was extensively tested by Maryland in the Magothy River, Severn River, and Tangier Sound from 1999 to 2002. Continuous monitoring was initially implemented by Maryland in the Pocomoke River to monitor water quality in response to the *Pfiesteria piscicida* outbreak in 1998. The implementation of shallow water monitoring technology will be coordinated between States and their partners employing similar equipment and methodology to ensure bay-wide compatibility and comparisons. Detailed information describing these technologies and the 1998 - 2004 results can be found on DNR's Eyes on the Bay web site at <http://www.eyesonthebay.net>

DNR will provide matching funds and will solicit other funding sources to expand shallow water monitoring capabilities. DNR will also provide staff, equipment and other resource to enhance shallow water monitoring with its partners and will coordinate with existing long-term water quality monitoring programs to ensure better understanding of estuarine processes.

The dates defined within this scope of work are for implementation of the shallow water monitoring for calendar year 2004 and reflect the work to be funded and completed within the budget period of July 1, 2004 - June 30, 2005.

### **1.2 Objectives and Problem Definition**

The objectives of the Shallow Water Monitoring Program are to 1) assess the newly developed Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow and open water habitats, 2) determine attainment or non-attainment of shallow water and open water habitats for their designated uses, 3) provide spatially and temporally intensive data in shallow water habitats to improve water quality mapping using interpolation, 4) assess SAV habitats and identify potential SAV restoration sites, 5) provide information to better understand ecosystem processes and the impact of extreme events (e.g. hurricanes, high flows) in shallow water and open water environments, and 6) provide information for calibrating the Bay Eutrophication and Watershed Model.

These objectives lead to management decisions. For example, if the monitoring results determine that a water body is out of attainment, the water body will be listed in the 305(b) report to the U.S. Environmental Protection Agency. If the causes of non-attainment are determined to be anthropogenic, the water body will be placed on the 303(d) list requiring a TMDL (total maximum daily load). Another example is the identification of potential SAV restoration sites. This information will be used by the SAV restoration strategy project to help select or eliminate sites from consideration for SAV restoration projects.

Water quality mapping provides information on variability and patchiness that is invaluable in establishing water quality criteria, and in determining attainment of those criteria. For example, spatial information on turbidity can be correlated to the spatial coverage of living resources such as bay grasses (SAV). This information can be used to determine and assess water clarity criteria necessary to support SAV growth, address the progress of meeting ambitious SAV restoration goals, and target specific areas for successful SAV restoration. Spatially intensive data can also help pinpoint localized areas of water quality concern, such as areas of low dissolved oxygen that can cause fish kills, and their possible links to nearby land uses or point sources. Spatial data can also be aggregated across watershed units to aid in the evaluation of entire systems.

Temporally intensive (continuous) monitoring provides information on the temporal variability of water quality. Continuous monitoring captures events that occur on short time scales (hours to days) or during times when it is impractical to deploy field crews. Continuous monitoring can capture early morning lows in dissolved oxygen as well as daytime and nighttime values of water quality parameters to provide scientists with the information necessary to fully assess criteria attainment in shallow water habitats. Continuous monitoring provides early warning of potential harmful algal blooms and low-dissolved oxygen related fish kills, allowing managers to coordinate appropriate supplemental sampling (e.g., plankton sampling). Continuous monitoring is instrumental in documenting the water quality impacts of episodic storm events.

### **1.3 Sampling Design and Data Quality Objectives**

#### **1.3.1 Parameters**

Parameters measured *in situ* include turbidity, specific conductance (to calculate salinity), water temperature, dissolved oxygen, fluorescence and total chlorophyll (to estimate chlorophyll *a*), pH and depth (see Appendices 10 and 11). Grab samples that are filtered on site are also collected at water quality mapping calibration stations and at continuous monitoring stations. Processed grab samples will be taken and sent to the Chesapeake Biological Laboratory's Nutrient Analytical Services Laboratory to be analyzed for the same suite of nutrients as those measured for the Chesapeake Bay Mainstem Program (chlorophyll *a*, total dissolved nitrogen, particulate nitrogen, nitrite, nitrite + nitrate, ammonium, total dissolved phosphorus, particulate phosphorus, orthophosphate, dissolved organic carbon, particulate carbon, silicic acid, total suspended solids and volatile suspended solids) plus particulate inorganic phosphorus and dissolved organic carbon and to the Maryland Department of Health and Mental Hygiene's Environmental Chemistry Laboratory for chlorophyll *a*, pheophytin and turbidity. In addition, Secchi depth and photosynthetic active radiation (PAR) measurements are taken at calibration stations to calculate light attenuation ( $K_d$ ). See Appendix 4 for details of the procedure for calculating light attenuation. See next section (Measured Parameters) for a list of all parameters and the methods associated with them.

### 1.3.2 *Spatial and Temporal Aspects*

Maryland will conduct shallow water monitoring in all 50 segments. Segments will be assessed for a three-year period. Available resources will dictate the number of segments assessed in each three-year period. These segments will be prioritized considering the following factors:

- Need for making listing or delisting decisions
- Potential importance as restoration site for living resources (e.g., oysters, SAV)
- Importance as living resource habitat (for example, Tangier Sound provides key grass bed habitat for blue crabs)
- Modeling needs
- Availability of partners to share costs and labor
- Logistics and efficiency considerations
- Geographic, size, and habitat type representativeness/equitability considerations
- Determine effect of major management action (before/after)

The continuous monitoring instruments will be deployed at predetermined sites in Maryland's tidal tributaries. Sampling sites for the 2004 season are depicted on the map in Figure 1. A three-year assessment has been completed on the Severn, Magothy, and Pocomoke Rivers. Eleven Chesapeake Bay tributaries have been identified for shallow water monitoring in Maryland in 2004, ranging from small systems to large systems with spatial coverage throughout Maryland:

- Bush River (Second year of assessments for this small system on the Upper Western Shore)
  - Stations located at Otter Point Creek (NERRS Site) and Lauderick Creek
- Chester River (Second year of assessments for this mid-sized system on the Upper Eastern Shore)
  - Stations located at Rolph's Wharf and Deep Landing
- Eastern Bay (First year of assessments for this large system on the Upper Eastern Shore)
  - Stations located at Kent Point and Hambleton Point
- Fishing Bay (Second year of assessments for this large system on the Lower Eastern Shore)
  - Stations located at Elliot Island and Bestpitch (Transquaking)
- Gunpowder River (Second year of assessments for this small system on the Upper Western Shore)
  - Stations located at Aberdeen Proving Ground and Mariner's Point Park
- Middle River (Second year of assessments for this small system on the Upper Western Shore)
  - Stations located at Strawberry Point and Cutter Marina
- Patuxent River (Second year of assessments for this large system in the Patuxent River Basin)
  - Stations located at CBL, Pin Oak, Benedict, King's Landing, Mataponi Creek (NERRS Site), Jug Bay (NERRS Site) and Iron Pot Landing (NERRS Site)
- Potomac River (First year of assessments for this large system in the Potomac River Basin)
  - Stations located at Piney Point, Sage Point (St. Mary's), Mattawoman Creek, Fenwick Shores, Piscataway Creek
- Rhode River (First year of assessments for this small system on the Upper Western Shore)
  - Station located at Smithsonian Environmental Research Center
- South River (First year of assessments for this small system on the Upper Western Shore)
  - Stations located at Harness Creek and Beards Creek
- West River (First year of assessments for this small system on the Upper Western Shore)
  - Station located at Shady Side

Detailed latitude and longitude continuous monitoring site location for 2004 is provided in Table 1. Detailed locational data collected by GPS on water quality mapping cruises will be associated with each



data point measured during the cruise and submitted to the Bay Program as part of routine data submissions.

**Table 1. 2004 Continuous monitoring stations.**

Station Name	Tributary	Station Description	Sample Depth (m)*	Station Depth (MLW) (m)	Latitude (NAD83)	Longitude (NAD83)
XJG4337	Bush River	Lauderick Creek	1.0 BS	1.3	39.4039	-76.2728
XJG7035	Bush River	Otter Point Creek	0.3 AB	0.5	39.4508	-76.2746
XHF0561	Chesapeake Bay	Sandy Point State Park	0.5 BS	1.5	39.0084	-76.3994
XHF0460	Chesapeake Bay	Sandy Point State Park	0.5 BS	1.7	39.0075	-76.4003
CHE0348	Chester River	Deep Landing	1.0 BS	1.7	39.2403	-75.9586
XIH0077	Chester River	Rolph's Wharf	1.0 BS	3.0	39.1666	-76.0387
XFG9164	Eastern Bay	Hambleton Point	1.0 BS	0.3	38.8194	-76.2259
XGF0681	Eastern Bay	Kent Point	1.0 BS	0.5	38.8440	-76.3653
XCH8097	Fishing Bay	Fishing Bay	1.0 BS	1.8	38.3000	-76.0056
XJG2718	Gunpowder River	Aberdeen Proving Ground	1.0 BS	1.2	39.3815	-76.3043
XJF4289	Gunpowder River	Mariner's Point Park	1.0 BS	1.5	39.4019	-76.3516
MDR0038	Middle River	Cutter Marina	1.0 BS	2.0	39.3206	-76.4397
FRG0002	Middle River	Strawberry Point	1.0 BS	1.8	39.3152	-76.4061
WXT0013	Patuxent River	Iron Pot Landing	0.3 AB	1.6	38.7960	-76.7208
PXT0455	Patuxent River	Jug Bay	0.3 AB	1.3	38.7813	-76.7137
MTI0015	Patuxent River	Mataponi	0.3 AB	0.6	38.7433	-76.7074
XED0694	Patuxent River	Benedict	0.5 AB	1.7	38.5103	-76.6772
XCF9029	Patuxent River	Chesapeake Biological Lab	0.5 AB	2.4	38.3167	-76.4526
PXT0311	Patuxent River	King's Landing	0.5 AB	1.8	38.6263	-76.6768
XDE4587	Patuxent River	Pin Oak	0.5 AB	1.2	38.4088	-76.5218
XFB0231	Potomac River	Fenwick	0.3 AB	0.5	38.6699	-77.1151
XEA3687	Potomac River	Piscataway	0.3 AB	1.4	38.5593	-77.1887
XFB2184	Potomac River	Mattawoman	0.3 AB	1.6	38.7016	-77.0259
XBF6843	Potomac River	Sage Point (St. Mary's)	0.5 AB	1.2	38.1135	-76.4285
XBE8396	Potomac River	Piney Point	0.5 AB	1.2	38.1378	-76.5058
XGE3275	Rhode River	SERC	1.0 BS	2.2	38.8860	-76.5415
ZDM0001	South River	Harness Creek Downstream	0.5 AB	1.6	38.9360	-76.5077
ZDM0002	South River	Harness Creek Upstream	0.5 AB	1.3	38.9365	-76.5074
XGE7059	South River	Beards Creek	1.0 BS	1.5	38.9495	-76.5687
TRQ0088	Transquaking River	Bestpitch	1.0 BS	2.7	38.4173	-75.9935
XGE0284	West River	West River	1.0 BS	1.6	38.8367	-76.5279

\* AB = Above Bottom, BS = Below Surface

Maryland DNR staff will be responsible for maintaining all continuous monitoring sites except for the two sites in the oligohaline and two sites for the mesohaline sections of the Patuxent estuary and the two sites in the mesohaline section of the Potomac River. The University of Maryland's Chesapeake Biological Laboratory (CBL) will manage the four Patuxent River sites using the same protocols and equipment as outlined in this QAPP. St. Mary's College River Project (SMCRP) will manage the two Potomac River sites using the same protocols and equipment as outlined in this QAPP. Maryland DNR will conduct all water quality mapping cruises except on the Patuxent estuary and the mesohaline section of the Potomac River. CBL will conduct water quality mapping cruises on all three segments on the

Patuxent, the tidal fresh, oligohaline and the mesohaline sections using the same protocols and equipment as outlined in this QAPP. SMCRP will conduct water quality mapping cruises on St. Mary's Creek and on the Potomac River from Piney Point to Point Lookout.

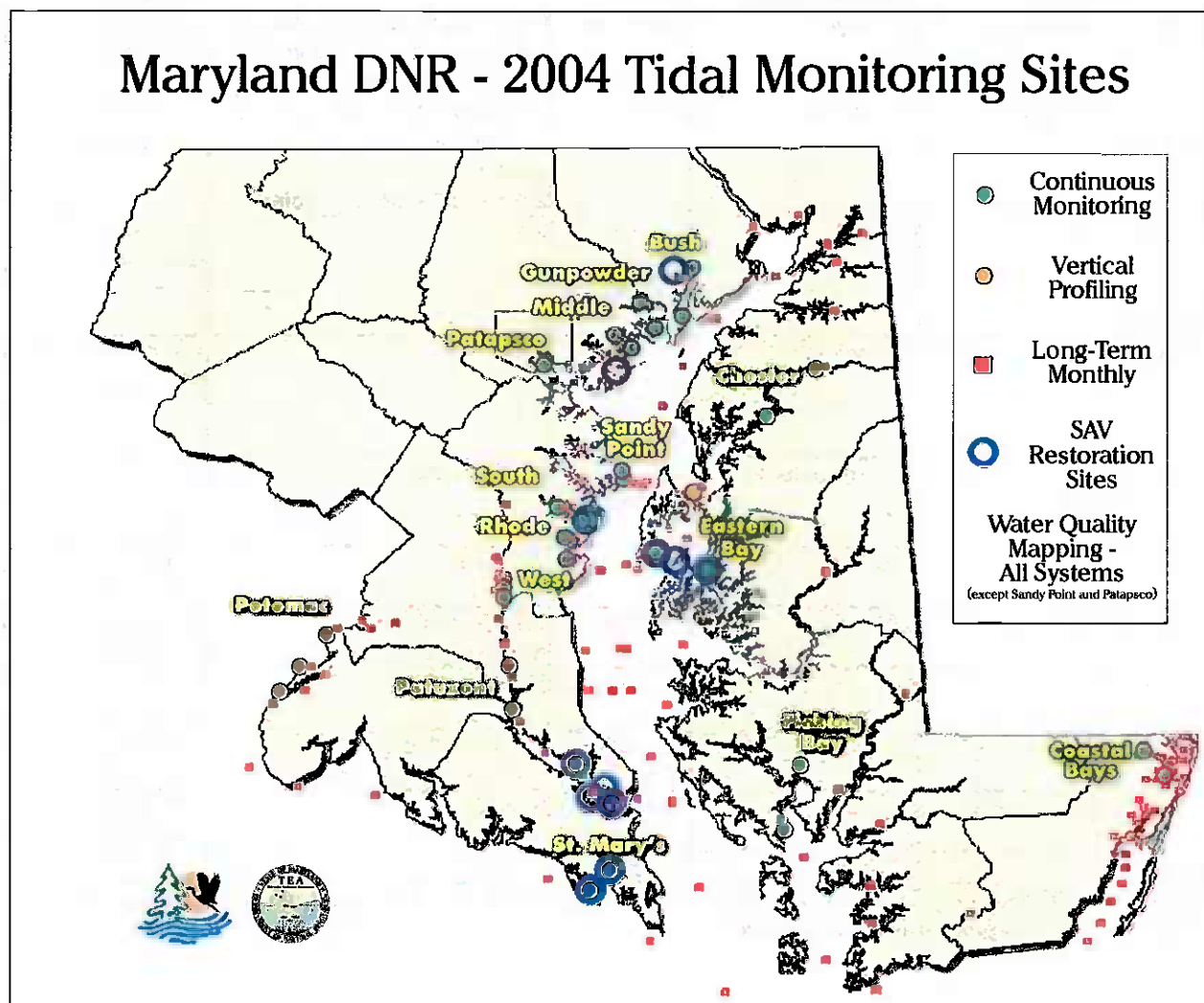


Figure 1. Map of 2004 continuous monitoring stations, water quality mapping systems, vertical profiling station and Maryland long-term tidal water quality monitoring stations.

## 2. MEASURED PARAMETERS

The Chesapeake Bay Shallow Water Quality Monitoring Program measures several physical and chemical parameters that are indicative of the Bay's eutrophication problem. Several "natural" properties such as salinity and temperature in the water column provide important information for interpretation of water quality indicators. For example, water clarity criteria differ based on the salinity regime.

Tables 2 and 3 list parameters measured *in situ* along with the resolution, range, accuracy and equipment used. Table 4 lists the parameters measured in the laboratory (from grab samples taken at calibration stations), their detection limits, methods references, and holding times and conditions.

**Table 2. Continuous monitoring *in situ* water column parameters.**

Parameter (Units)	Resolution	Range	Accuracy	Equipment
Specific Conductance (mS/cm=mmhos/cm)	0.001 to 0.1 mS/cm (range-dependent)	0 to 100 mS/cm	0.5% of reading + 0.001 mS/cm	YSI 6600 6560 probe
Dissolved Oxygen (mg/L)	0.01 mg/L	0 to 50 mg/L	0 to 20 mg/L; 2% of reading or 0.2 mg/L, whichever is greater; 20 to 50 mg/L; 6% of reading	YSI 6600 6562 probe
Dissolved Oxygen (% saturation)	0 to 500 %	0 to 500 %	0 to 200%; 2% of reading or 2% air saturation, whichever is greater; 200 to 500%; 6% of reading	YSI 6600 6562 probe
Fluorescence	0.1%FS	0 to 400 µg/L Chl; 0 to 100% FS	NA	YSI 6600 6025 probe
Total Chlorophyll	0.1 µg/L Chl	EM 470 nm; EX 650 - 700 nm; 0 - 400 µg/l	NA	YSI 6600 6025 probe
Photosynthetic Active Radiation (PAR)	See Appendix 4	See Appendix 4	See Appendix 4	LI-192SA and LI-190SA
pH (pH units)	0.01 units	0 to 14 units	0.2 units	YSI 6600 6561 probe
Salinity (ppt)	0.01 ppt	0 to 70 ppt	1% of reading or 0.1 ppt, whichever is greater	YSI 6600 6560 probe
Secchi depth (m)	NA	0.1 m (lower limit)	NA	Secchi disk (20 cm or 25.2 cm)
Turbidity (NTU)	0.1 NTU	0 to 1000 NTU	5% of reading or 2 NTU, whichever is greater	YSI 6600 6136 probe*
Water Temperature (°C)	0.01°C	-5 to 45 °C	0.15 °C	YSI 6600 6560 probe
Depth	0.001 m	0 - 9 m	0.02 m	

\* Between 1998 and 2003 the older model 6026 turbidity probe was in use in some instruments. Beginning in 2004, the 6136 turbidity probe was used exclusively.

**Table 3. Water Quality Mapping *in situ* water column parameters.**

Parameter (Units)	Resolution	Range	Accuracy	Equipment
Specific Conductance (mS/cm=mmhos/cm)	0.001 to 0.1 mS/cm (range-dependent)	0 to 100 mS/cm	0.5% of reading + 0.001 mS/cm	YSI 6600 6560 probe
Dissolved Oxygen (mg/L)	0.01 mg/L	0 to 50 mg/L	0 to 20 mg/L; 2% of reading or 0.2 mg/L, whichever is greater; 20 to 50 mg/L; 6% of reading	YSI 6600 6562 probe
Dissolved Oxygen (% saturation)	0 to 500 %	0 to 500 %	0 to 200%; 2% of reading or 2% air saturation, whichever is greater; 200 to 500%; 6% of reading	YSI 6600 6562 probe
Fluorescence	0.1%FS	0 to 400 µg/L Chl; 0 to 100% FS	NA	YSI 6600 6025 probe
Total Chlorophyll	0.1 µg/L Chl	EM 470 nm; EX 650 - 700 nm; 0 - 400 µg/l	NA	YSI 6600 6025 probe
Photosynthetic Active Radiation (PAR)	See Appendix 4	See Appendix 4	See Appendix 4	LI-192SA and LI-190SA
pH (pH units)	0.01units	0 to 14 units	0.2 units	YSI 6600 6561 probe
Salinity (ppt)	0.01 ppt	0 to 70 ppt	1% of reading or 0.1 ppt, whichever is greater	YSI 6600 6560 probe
Secchi depth (m)	NA	0.1 m (lower limit)	NA	Secchi disk (20 cm or 25.2 cm)
Turbidity (NTU)	0.1 NTU	0 to 1000 NTU	5% of reading or 2 NTU, whichever is greater	YSI 6600 6136 probe*
Water Temperature (°C)	0.01°C	-5 to 45 °C	0.15 °C	YSI 6600 6560 probe
Depth	0.001 m	0 - 9 m	0.02 m	
Position	15 m	NA	5 m	Handheld Garmin e-Trex Global Positioning Unit

\* Between 1998 and 2003 the older model 6026 turbidity probe was in use in some instruments. Beginning in 2004, the 6136 turbidity probe was used exclusively.

#### Sources For Tables 2 and 3:

Rohland, F.M., W.R. Boynton, R.M. Stankelis, B.W. Bean, H.J. Pine. 2002. *Maryland Chesapeake Bay Water Quality Monitoring Program, Ecosystem Processes Component (EPC), Quality Assurance Project Plan for Water Quality Monitoring in Chesapeake Bay for FY 2003, July 2002-June 2003, Revision 7*. Prepared for the Maryland Department of Natural Resources, September 30, 2002. University of Maryland Center for Environmental Sciences, Chesapeake Biological Laboratory, P.O. Box 38, Solomons, MD. Technical Report Series No. TS-343-01-CBL. Ref. No. [UMCES]CBL 01-0306b.

YSI Incorporated. January 2002. YSI 6-Series Manual. Available online at:

[http://www.ysi.com/extranet/EPGKL.nsf/8cb9f9b96c40c0f685256b1a006610d1/5fc62de987236efb85256c8d00765458/\\$FILE/069300B.pdf](http://www.ysi.com/extranet/EPGKL.nsf/8cb9f9b96c40c0f685256b1a006610d1/5fc62de987236efb85256c8d00765458/$FILE/069300B.pdf)

**Table 4. Shallow Water Monitoring Program Grab Sample Water Column Parameters, Detection Limits, Methods References, and Holding Times and Conditions.**

Parameter (Units)	Detection Limit (or Range)	Method Reference	Holding Time and Condition
Orthophosphate (mg/L as P)	0.0006 mg/L	EPA method 365.1 (EPA 1979)	Freezing-28 d
Total Diss. Phosphorus (mg/L as P)	0.001 mg/L	Valderrama (1981)	Freezing-28 d
Particulate Phosphorus (mg/L as P)	0.0024 mg/L	Aspila et al. (1976)	Freezing-28 d
Particulate Inorganic Phosphorus (mg/L as P)	0.0024 mg/L	Aspila et al. (1976) (without combusting the pad)	Freezing-28 d
Nitrite (mg/L as N)	0.0002 mg/L	EPA method 353.2 (EPA 1979)	Freezing-28 d
Nitrite + Nitrate (mg/L as N)	0.0007 mg/L	EPA method 353.2 (EPA 1979)	Freezing-28 d
Ammonium (mg/L as N)	0.003 mg/L	EPA method 350.1 (EPA 1979)	Freezing-28 d
Total Dissolved Nitrogen (mg/L as N)	0.02 mg/L	D=Elia et al. (1977) Valderrama (1981)	Freezing-28 d
Particulate Nitrogen (mg/L as N)	0.0105 mg/L	EPA method 440.0 (EPA 1997)	Freezing-28 d
Diss. Organic Carbon (mg/L as C)	0.15 mg/L	Sugimura and Suzuki (1988)	Freezing-28 d
Particulate Carbon (mg/L as C)	0.0633 mg/L	EPA method 440.0 (EPA 1997)	Freezing-28 d
Silicic Acid (mg/L as Si)	0.01 mg/L	Technicon (1977)	4 °C - 28 d
Total Suspended Solids (mg/L)	2.4 mg/L	EPA method 160.2 (with slight modification) EPA (1979); APHA (1975)	Freezing-28 d
Total Volatile Solids	0.9 mg/L	APHA method 208 E (with modification) APHA (1975)	Freezing-28 d
Turbidity* (NTU)	0.5 NTU	EPA method 180.1 (nephelometric)	4 °C - 48 h
Chlorophyll <i>a</i> (µg/L)	0.1 µg/L	APHA (1981)	Freezing-28 d
Pheophytin <i>a</i> (µg/L)	0.1 µg/L	APHA (1981)	Freezing-28 d

\* See Appendix 5 for a description of the turbidity method used by the Maryland Department of Health and Mental Hygiene.

**References For Table 4:**

American Public Health Association (APHA). 1981. Method 1002 G, chlorophyll (trichromatic), in *Standard Methods for the Examination of Water and Wastewater*, 17<sup>th</sup> ed.

American Public Health Association (APHA). 1975. Method 208D, total nonfilterable residue dried at 103-105°C (total suspended matter), in *Standard Methods for the Examination of Water and Wastewater*, 14<sup>th</sup> Edition. American Public Health Association: Washington, D.C. 1193 p.

- American Public Health Association (APHA). 1975. Method 208E ( with modification). Total volatile and fixed residue at 550° C in *Standard Methods for the Examination of Water and Wastewater*, 14<sup>th</sup> Edition. American Public Health Association: Washington D.C. 1193 p.
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- Michael, Bruce and Elizabeth Ebersole. 2002. Quality Assurance Project Plan for the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program - Chemical and Physical Properties Component for the period July 1, 2002 - June 30, 2003. Prepared by Maryland Department of Natural Resources, Tidewater Ecosystem Assessment for U.S. Environmental Protection Agency Chesapeake Bay Program.
- Parsons, T.R., Takahashi, M. and B. Hargrave. 1977. *Biological Oceanographic Processes*. Pergamon Press. Oxford. 332 p. (pages 71-85).
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- Sugimura, Y. and Y. Suzuki. 1988. A high temperature catalytic oxidation method for the determination of non-volatile dissolved organic carbon in seawater by direct injection of a liquid sample. *Mar. Chem.* 24:105 - 131.
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- US Environmental Protection Agency (EPA). 1979. *Methods for Chemical Analysis of Water and Wastes*. EPA-600/4-79-020. 460 p.
- Valderrama, J. C. 1981. The simultaneous analysis of total nitrogen and total phosphorus in natural waters. *Mar. Chem.* 10:109-122.
- Welch, P.S. 1948. Chapter 11 in *Limnological Methods*. Blakiston: Philadelphia, PA. pp. 159-167.



### **3. FIELD MEASUREMENTS AND SAMPLING**

#### **3.1. Continuous Monitoring**

Each continuous monitoring station is equipped with a YSI 6600 sonde. Beginning in 2004, all YSI 6600 data sondes will be equipped with Extended Deployment Systems (EDS). The EDS has a wiper system that allows the continuous monitoring sondes to be deployed for longer periods of time without suffering a degradation of data quality as a result of biofouling. Each continuous monitoring sonde records nine water quality parameters every 15 minutes. The nine water quality parameters measured continuously are water temperature, specific conductance, salinity, dissolved oxygen, turbidity (NTU), fluorescence and total chlorophyll (used to estimate chlorophyll *a*), pH and depth. Continuous monitoring sondes are positioned in the water column in either a floating configuration that suspends the sonde at some distance below the surface (usually 1-meter), or in an anchored configuration that fixes the sonde at some distance above the bottom. The sonde is positioned in the water column in either a floating configuration or a fixed configuration depending on the geographic area being monitored and the monitoring goals for that segment.

Continuous monitoring sondes in a floating configuration are suspended from a float inside of a 4-inch diameter PVC pipe with 2-inch holes drilled every 4 inches below the waterline to allow for water exchange. Sondes in a fixed configuration are also housed inside a perforated 4-inch diameter PVC pipe, and a bolt is used to hold the negatively buoyant sonde at a fixed depth above the sediment bottom. At selected sites, telemetry is used to transmit the data in near real-time to DNR's Eyes on the Bay web site (<http://www.eyesonthebay.net>). The telemetry system is comprised of a field component located at each sampling site and an office component located at the Bay Program offices in Annapolis. The field component consists of an electrical box housing a CR10X data logger, which stores data collected by the data sonde, a battery and solar panel to supply power, and either an analog or digital cellular modem. Several times a day, the computer server located at the Bay Program office contacts the data logger located at each sampling site via TCP/IP communications and then uploads, archives, and updates the data display on the Eyes on the Bay web site. These data are available immediately on the Internet, allowing the general public to view near real-time water quality data. Details of the steps for installing, calibrating, deploying, and retrieving the YSI instruments are provided in Appendix 7.

In addition to the parameters measured by the sonde, Secchi depth and light attenuation are measured weekly from May to October, and grab samples are taken and filtered on-site or immediately after returning to the lab. See Appendix 3 for a description of the filtering procedures. The processed samples are sent to the Nutrient Analytical Services Laboratory (NASL) at the Chesapeake Biological Laboratory and to the Maryland Department of Health and Mental Hygiene (DHMH) for analysis. These results will be used to analyze relationships between the water quality parameters measured by each continuous monitor and nutrient component. Some of the lab data are also used to check the YSI data for accuracy. Parameters analyzed at NASL total dissolved nitrogen, particulate nitrogen, nitrite, nitrite + nitrate, ammonium, total dissolved phosphorus, particulate phosphorus, orthophosphate, dissolved organic carbon, particulate carbon, silicic acid, total suspended solids, volatile suspended solids, particulate inorganic phosphorus and dissolved organic carbon. Parameters analyzed at DHMH include chlorophyll *a*, pheophytin and turbidity.

#### **3.2 Water Quality Mapping**

Water quality mapping is conducted using DATAFLOW, a shipboard system of geospatial equipment and water quality probes that measure water quality parameters from a flow-through stream of water collected near the water's surface. The seven water quality parameters measured are water temperature, salinity, conductivity, dissolved oxygen, turbidity (NTU), fluorescence (used to estimate chlorophyll *a*) and pH.

The water is pumped through a ram (pipe), through the sensors, and then discharged overboard. DATAFLOW includes a hand-held Garmin e-Trex global positioning system (GPS), a YSI 6600 sonde with a flow-through chamber, a YSI 6562 dissolved oxygen probe, a YSI 6560 conductivity/temperature probe, a 6026 turbidity probe, and a 6025 chlorophyll probe. The sonde transmits the data from the sensors to a YSI 650 data logger. Each water quality datum is associated with a date, time, water depth, and GPS coordinate (WGS84).

DATAFLOW allows data to be collected rapidly (approximately every four seconds) while the boat is traveling at speeds of up to 25 knots. The DATAFLOW system is compact and can be fit onto a small boat, allowing sampling in shallow water and the ability to map an entire small tributary such as the Severn River in less than a day. The distance between samples depends on vessel speed; generally at least one observation is collected approximately every 30 meters (100 feet).

The DATAFLOW system samples water at approximate 0.5-m depths below the surface. At calibration stations, grab samples also are collected at 0.5-m depth and filtered on site. See Appendix 3 for a description of the filtering procedures. The processed samples are sent to the Nutrient Analytical Services Laboratory (NASL) at the Chesapeake Biological Laboratory and to the Maryland Department of Health and Mental Hygiene (DHMH) for analysis. Parameters analyzed at NASL total dissolved nitrogen, particulate nitrogen, nitrite, nitrite + nitrate, ammonium, total dissolved phosphorus, particulate phosphorus, orthophosphate, dissolved organic carbon, particulate carbon, silicic acid, total suspended solids, volatile suspended solids, particulate inorganic phosphorus and dissolved organic carbon. Parameters analyzed at DHMH include chlorophyll *a*, pheophytin and turbidity. In addition, Secchi depth and photosynthetic active radiation (PAR) measurements are taken at calibration stations to calculate light attenuation ( $K_d$ ). The calibration station locations are selected to:

- 1) sample the greatest possible range of water quality conditions found during each cruise;
- 2) sample a broad spatial area;
- 3) overlap with long-term fixed monitoring and continuous monitoring stations.

For more details on equipment and sampling design, see Boynton et al. 2002 and Rohland et al. 2002.

#### **4. LABORATORY ANALYSIS**

Turbidity is analyzed at the Maryland Department of Health and Mental Hygiene's (DHMH) Environmental Chemistry Division for only those samples collected by DNR personnel. Active chlorophyll *a* is analyzed by DHMH for all samples collected. For details, refer to DHMH's chlorophyll analysis Standard Operating Procedures available in the Quality Assurance Project Plan for the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program Chemical and Physical Properties Component for the period July 1, 2002 - June 30, 2003 (Michael and Ebersole 2002).

All other laboratory-measured parameters are analyzed at the University of Maryland's Chesapeake Biological Laboratory (CBL), Nutrient Analytical Services Laboratory. For details, refer to CBL's Standard Operating Procedures available in the Quality Assurance Project Plan for the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program Chemical and Physical Properties Component for the period July 1, 2002 - June 30, 2003 (Michael and Ebersole 2002).

To ensure that samples are processed within the holding times, samples are packed in ice immediately after filtering and taken to the field office and stored in a freezer. Turbidity samples are delivered to DHMH on the day they are collected for analysis that day or the day after. The frozen samples are packed in ice and driven to NASL and DHMH weekly to be processed. NASL and DHMH process and



analyze the samples within the holding time periods established under the specific parameter method reference and listed in Table 4.

## 5. DATA MANAGEMENT, VERIFICATION AND DOCUMENTATION

### 5.1 Continuous Monitoring

At continuous monitoring stations where biofouling rates are not extremely high, the sondes are retrieved, calibrated and replaced every two weeks from April to October. At those stations where biofouling rates are extremely high, the continuous monitoring sondes are retrieved, calibrated and replaced weekly during high fouling periods. Three National Estuarine Research Reserve (NERR) sites on the upper Patuxent and 1 NERR site at Otter Point Creek on the Bush River are maintained year round unless severe icing in January or February prohibits deployment. For these stations the continuous monitoring sondes are retrieved, calibrated and replaced every two weeks between November and March.

In the field, before a continuous monitoring sonde is replaced, a three-way *in situ* match-up is conducted. The new (freshly calibrated) sonde is suspended next to the PVC tube, at the same depth of the old (deployed) sonde in the tube. The discrete check sonde (usually a Hydrolab) is also suspended in the water at the same depth. A synchronized reading is taken at the next 15-minute interval with the old, new and check sondes. A second synchronized reading is taken at the next 15-minute interval with just the old and the new sondes. After two synchronized readings have been taken, a water column profile is conducted (Appendix 14). After the water column profile, the old sonde is removed from the PVC tube and the tube is cleaned with a Webster duster brush to remove biofouling and clear debris from the inside and outside of the tube as well as from any telemetry cables or the floating mechanism (if applicable). Once everything has been cleaned, the new sonde is placed in the PVC tube. This three-way comparison assures that the new and old sondes are both reading each parameter within a certain tolerance. The check sonde allows for notation on whether or not the parameters are fluctuating or stable.

The retrieved continuous monitoring sonde is brought back to the field office where it is allowed to equilibrate overnight to standard temperature and pressure in a 100% saturated air environment. After equilibration, a dissolved oxygen check is conducted as outlined in Appendix 2, the data are uploaded to a personal computer using YSI's Ecowatch software, and the remaining post-calibration procedures are conducted as outlined in Appendix 2.

After post-calibration has been completed, the data are subjected to intense quality assurance (QA) and quality control (QC) checks to ensure that the data are not erroneous and that they are within the range of the sensor instrumentation (Appendix 1). Data from the three-way *in situ* match-up is first used to determine if a specific probe has drifted outside of an acceptable range (Table 5). Data are rejected during the QA/QC checks when post-calibration drift exceeds the limits stated in Table 5 in both the post-calibration and the in-situ comparables, or when data are clearly associated with probe failures. Section 5.3 describes the data management procedures that are common to the continuous monitoring and water quality mapping projects.

Data from telemetered stations are examined daily by DNR staff. Additionally, several automated programs have been put in place that examine the real-time data and notify DNR staff via e-mail when

**Table 5. Acceptable drift tolerances for YSI 6600EDS sondes following post-calibration check.**

Parameter	Value
Chlorophyll	±5 % of true value
Dissolved Oxygen	±0.5 mg/L
pH	±0.2 pH units
Specific Conductance	±5 % of true value
Turbidity	±5 % of true value
Water Temperature	±0.2 °C

chlorophyll levels (algal blooms) and low dissolved oxygen events may be occurring so that supplemental sampling may be conducted. Automated programs also alert DNR staff via e-mail when equipment malfunctions and probe failures may be occurring at real-time continuous monitoring stations. To ensure the quality of the data presented on the Eyes on the Bay (<http://www.eyesonthebay.net>) website, the real-time data is replaced with the QA/QC'd data generated after continuous monitoring sonde replacement. While every effort is made to ensure the quality of the data presented on Eyes on the Bay, DNR does place disclaimers on the web site that state the following:

NOTE: Results displayed in "Current Results" are provisional and have not undergone full Quality Assurance/Quality Control procedures. Results in "Archived Results" also may not have undergone full Quality Assurance/Quality Control procedures. Although Maryland DNR believes the data presented here are correct, we cannot guarantee their accuracy at this time. Due to the technologies being used for turbidity, fluorescence and depth measurements, these results in particular may be subject to inaccuracies.

At the end of the monitoring season, DNR staff check for additional erroneous data, perform data QA/QC procedures and calculate chlorophyll *a*. Staff plot all of the data and then thoroughly research any outliers or other unusual values. For example, staff compare values outside the normal range to historic values and values elsewhere in the Bay, consider weather events, and consult with field staff regarding possible legitimate causes for those values. In cases where values are not legitimate, they are masked in the database with the approval of the field staff and the Quality Assurance Officer.

## **5.2 Water Quality Mapping**

Water Quality Mapping (WQM) is generally conducted once monthly in each sampled tributary from April-October. For tributaries with submerged aquatic vegetation restoration, specific monitoring projects, or in polyhaline segments sampling may begin in March. In 2004, 13 systems are being monitored in Maryland. Cruise tracks vary depending on the system. In general, a square-wave pattern is followed by alternately sampling shallow shoreline areas and open, deeper waters while traveling up and downriver. Alternative cruise paths may be followed if tributary size or shape dictates otherwise. Cruise patterns are selected to obtain representative coverage of shallow water habitats and open waters so that segment-wide criteria can be assessed as accurately as possible. Navigational issues and placement of representative calibration sites also determines ultimate cruise tracks for WQM.

During data collection, field personnel keep a detailed logbook that documents any incidents or observations that may affect the integrity or interpretation of the data. Such observations may include perturbation of bottom sediments by the boat, observances of algal blooms or equipment malfunctions. After data collection, field personnel use the Shallow Water Monitoring QA/QC macro (See Appendix 13) to format data, highlight erroneous values, and add appropriate error codes based on field notes. Original data files are named with a three-letter segment designation, an eight digit data and an "R" for raw data file (e.g. SEV05272004R). Files that have been through the QAQC process are labeled with an "Q", instead of a "R". After initial QA/QC by field personnel, data files are reviewed by a data analyst, which includes the added step of viewing data within a GIS context. This procedure can highlight positional errors and elucidate errors that can only be viewed within a geographical display.

Preliminary maps of chlorophyll, dissolved oxygen, turbidity, water temperature and salinity are created and placed on the Internet at [www.eyesonthebay.net](http://www.eyesonthebay.net). Maps are interpolated using a default inverse distance weighted procedure. These maps give an overall perspective of water quality conditions and are meant for general reference, not for detailed analysis. In the near future, a searchable water quality mapping database system will be placed on the Eyes on the Bay website. CBP-compliant metadata is

being created for WQM data, and will be available in association with any data downloads from the website.

### 5.3 Data Management

All shallow water monitoring data (continuous monitoring and water quality mapping) are maintained in a Shallow Water Monitoring database as part of Maryland DNR's Water Quality Monitoring Program. Data that are rejected during QA/QC checks are never deleted. Erroneous data are masked with an appropriate error code (see Appendix 12) rather than deleted. This ensures that all raw data are archived should the need ever arise to evaluate those values in the future. The potential also exists that future techniques and technologies may make it possible to utilize data that were previously rejected. After the data from a deployment have undergone QA/QC checks, the QA/QC'd data files are transferred to an internal network directory where they are automatically inserted into DNR's Shallow Water Monitoring database. Backup redundant copies of all raw data and QA/QC'd data are also kept. A new data submission system is currently being developed and tested that would automatically submit data from the Shallow Water Monitoring database to the Bay Program via FTP and XML communications protocols (Figures 2 and 3). This new data submission method will streamline data submission and sharing between DNR and Bay Program by reducing the Bay Program's role in data management. Any changes made to DNR's database will be automatically transmitted to the Bay Program and mirrored in their database. This will significantly reduce or eliminate issues associated with data versioning. This new system will ensure that both DNR and the Bay Program are working from the same dataset at all times.

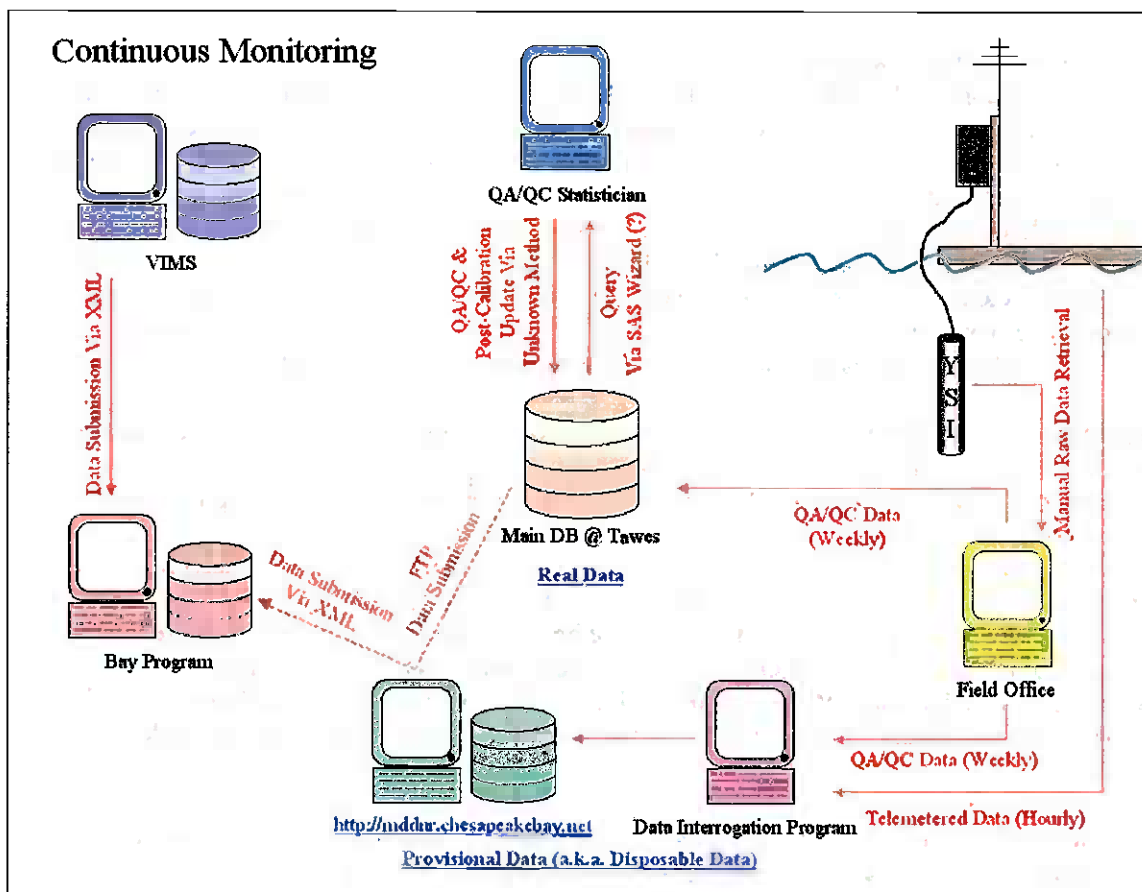


Figure 2. Conceptual diagram of continuous monitoring data management components, including automated data submission from DNR to the Bay Program.

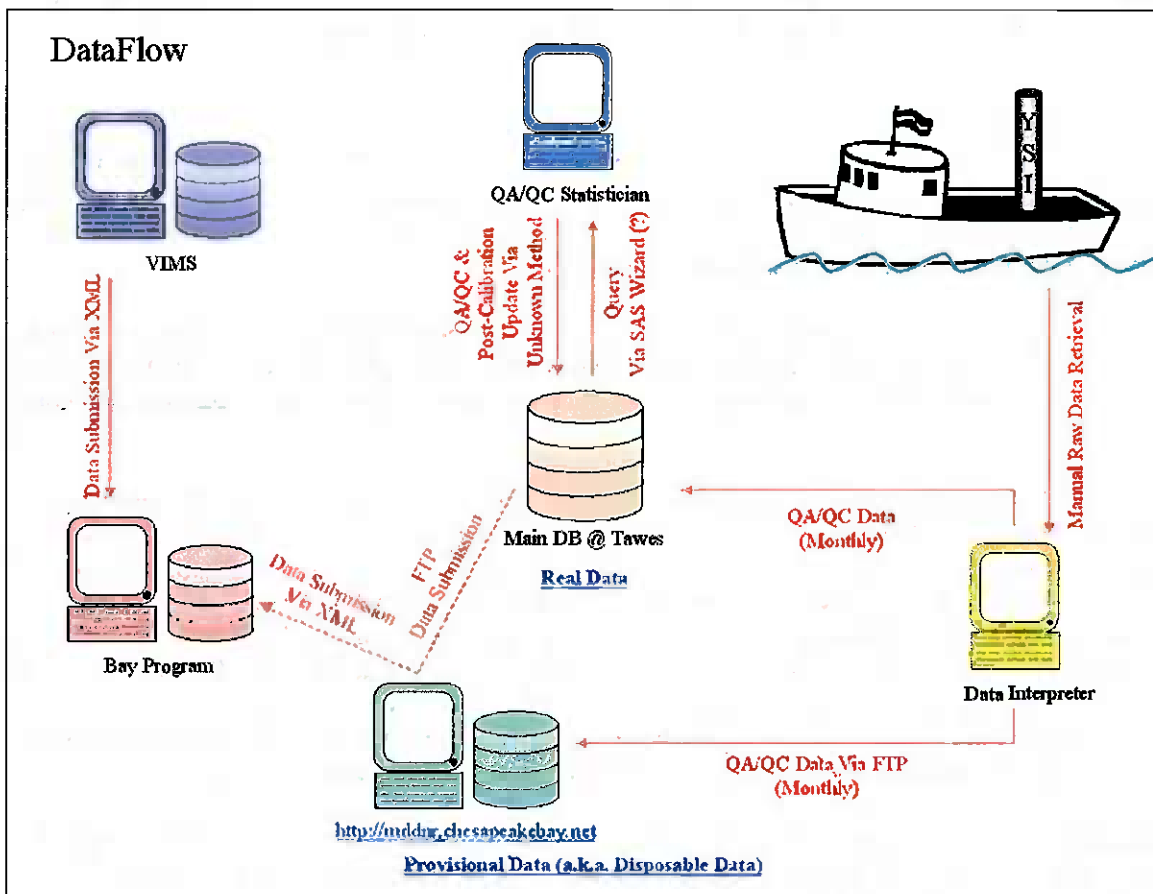


Figure 3. Conceptual diagram of water quality mapping data management components, including automated data submission from DNR to the Bay Program.

#### 5.4 Documentation and Records

Documentation and records maintained by the continuous monitoring project and the water quality mapping project include YSI 6200EDS Calibration and Post-Calibration Procedures (Appendix 2), Continuous Monitoring and Water Quality Mapping Filtering Methods (Appendix 3), Photosynthetic Active Radiation Protocol (Appendix 4), Continuous Monitoring Procedures (Appendix 7), Continuous Monitoring Instrument Calibration and Comparison Tables (Appendix 8), YSI 6600EDS Calibration Log (Appendix 9), Continuous Monitoring Data Verification and Management Procedures (Appendix 13), and Water Quality Mapping Data Verification and Management Procedures (Appendix 14).

### 6. PROJECT QUALITY ASSURANCE/QUALITY CONTROL

An initial quality assurance (QA) and quality control (QC) check is performed by field staff, who inspect all data for outliers and mask outliers in the data set as deemed appropriate before reporting any data. Field staff also mask any data for parameters that did not post-calibrate within specifications. See Tables 2, 3 and 5 in Sections 2 and 5 for limits on accuracy and instrument drift. See Appendix 2 (YSI 660EDS Calibration and Post-Calibration Procedures) and Appendices 14 and 15 (Continuous Monitoring and Water Quality Mapping Data Verification and Management Procedures) for a description of QA/QC and calibration procedures used by the field staff. Additional quality assurance and control is performed by

members of our staff to identify any erroneous data missed in the initial QA/QC, compare current data to historical data, and to post-calibrate certain parameters such as chlorophyll.

## **6.1 Accuracy**

The accuracy (closeness to the true value) of the collected data is controlled and assured by the proper use, calibration, and maintenance of both field and laboratory equipment for the measurement of physical and chemical parameters. All instruments are identified by a unique number, used as an index for documentation of calibration, repair, and preventive maintenance.

Daily quality control checks (including the running of blanks and standards) are used to control and assure laboratory accuracy. See Michael and Ebersole (2002; Appendices VII and VIII) for details on the frequency of running blanks and standards and for additional procedures for laboratory quality assurance and control.

Accuracy of laboratory results is also assessed through DNR's participation in the Chesapeake Bay Coordinated Split Sample Program (CSSP), a split sampling program in which the coordinated split samples are analyzed by five laboratories involved in Chesapeake Bay monitoring. CSSP was established in June 1989 to establish a measure of comparability between sampling and analytical operations for water quality monitoring throughout the Chesapeake Bay and its tributaries. DNR follows the protocols in the *Chesapeake Bay Coordinated Split Sample Program Implementation Guidelines* (EPA 1991) and its revisions. Split samples are collected quarterly. Results are analyzed by appropriate statistical methods to determine if results differ significantly among labs. When a difference occurs, discussion begins regarding techniques and potential methods changes to resolve discrepancies.

Additionally, CBL and DHMH participate two times per year in the United States Geologic Survey (USGS) reference sample program and permit USGS to release the results to the Chesapeake Bay Program Quality Assurance Officer.

Procedures to control and assure the accuracy of field measurements involve the calibration of field instruments, the verification of these calibrations, equipment maintenance, and collection of filter blanks.

## **6.2 Precision**

Precision (repeatability) of the chemical analytical methods is determined and documented from duplicate analyses. The protocols for duplicate analyses in the laboratory are described in the Standard Operating Procedures for CBL and DHMH, found in Appendices VII and VIII of the Quality Assurance Project Plan for the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program - Chemical and Physical Properties Component for the period July 1, 2002 - June 30, 2003 (Michael and Ebersole 2002).

## **6.3 Data Review and Data Verification**

Data review and data verification ensure the quality assurance and quality control of data. These are discussed in Section 5 above.



#### **6.4 Audits**

Performance audits for chemical analyses conducted at the University of Maryland's Chesapeake Biological Laboratory are based on the results of samples distributed by the EPA Chesapeake Bay Program Blind Audit Program. These samples must fall within the 95% confidence interval for acceptance. If results fall outside this range, corrective actions for each parameter and measurement are taken. CBL prepares the blind audit samples for all CBP participating laboratories and also analyzes some of those samples. For dissolved nitrogen and dissolved phosphorus, a laboratory quality assurance officer determines the concentrations in the ampules, prepares the concentrates, and seals the ampules. A different person then analyzes the sample blindly. For the particulate fractions (particulate carbon/particulate nitrogen and particulate phosphorus), samples are filtered and then placed in pouches in the freezer until they are ready to be sent to the other CBP participating laboratories - Old Dominion University's Applied Marine Research Laboratory, University of Maryland's Horn Point Laboratory, Virginia Institute of Marine Science, Virginia Division of Consolidated Laboratory Services, Pennsylvania Department of Environmental Resources, Virginia Polytechnic Institute's Occoquan Laboratory, Maryland Department of Health and Mental Hygiene, District of Columbia Department of Health, Philadelphia Academy of Science and, finally, Chesapeake Biological Laboratory, itself.

Once annually, the EPA Chesapeake Bay Program quality assurance officer conducts an onsite audit of the mainstem laboratory and field programs. The DNR Quality Assurance Officer communicates on a weekly basis with the field program staff and confers with the laboratory quality assurance officers to ensure that all aspects of the program are being conducted properly.

#### **6.5 Data Quality Indicators**

To ensure that data are of the quality required to support Chesapeake Bay Program management decisions, Maryland's Shallow Water Quality Monitoring Program strives to provide monitoring data of known and consistent quality to the CBPO by generally following the guidelines outlined in Section E of the *Recommended Guidelines for Sampling and Analysis in the Chesapeake Bay Monitoring Program*, August 1996 (EPA 1996). These guidelines recommend precision goals of field and lab measurements of <20 percent of the coefficient of variation; accuracy goals within 80 to 120 percent, and the completeness goals of 100 percent. Detection limit ranges are provided in Tables 2 and 3 above.

### **7. DATA ANALYSIS AND REPORTING**

As noted above, the objectives of the Shallow Water Monitoring Program are to 1) assess the newly developed Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow and open water habitats, 2) determine attainment or non-attainment of shallow water and open water habitats for their designated uses, 3) provide spatially and temporally intensive data in shallow water habitats to improve water quality mapping using interpolation, 4) assess SAV habitats and identify potential SAV restoration sites and 5) provide information to better understand ecosystem processes in shallow water and open water environments.

Real-time data (uploaded from transmitters hourly) and near-time data (uploaded every two weeks) will be available on the DNR Eyes on the Bay web site (<http://www.eyesonthebay.net>). These data are not quality assured and will be identified as such. Semi-annual progress reports will be provided to the Chesapeake Bay Program January 15, 2005 and July 15, 2005.

## 8. PROJECT ORGANIZATION AND RESPONSIBILITY

This section lists the individuals responsible for the major aspects of the Chemical and Physical Properties Component of Maryland's Chesapeake Bay Water Quality Monitoring Program.

Director and Principal Investigator: Bruce Michael, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, [bmichael@dnr.state.md.us](mailto:bmichael@dnr.state.md.us), 410-260-8630.

**RESPONSIBILITIES:** The director and principal investigator is responsible for overseeing the administrative aspects of the program including fiscal management, coordination among other DNR managers and coordination with cooperating agencies and institutions. This individual is also responsible for the technical design, conduct and data analysis of the program.

Quality Assurance Officer: Bruce Michael, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, [bmichael@dnr.state.md.us](mailto:bmichael@dnr.state.md.us), 410-260-8630.

**RESPONSIBILITIES:** The quality assurance officer is responsible for documenting and assuring the conduct of field, laboratory, and data management procedures that comprise this study.

Field Sampling Operations: Sally Bowen, Project Chief, Monitoring Field Office, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, [sbowen@dnr.state.md.us](mailto:sbowen@dnr.state.md.us), 410-990-4528.

**RESPONSIBILITIES:** This individual is responsible for administration of the field sampling activities including sample collection, sample storage and sample delivery to laboratories at all continuous monitoring sites and all but four of the water quality mapping sites.

Field Sampling Operations: Bob Stankelis, Center for Environmental Science, Solomons, Maryland 20688, [stankeli@cbl.umces.edu](mailto:stankeli@cbl.umces.edu), 410-326-7268.

**RESPONSIBILITIES:** This individual is responsible for administration of the field sampling activities including sample collection, sample storage and sample delivery to laboratories for four of the water quality mapping sites in the oligohaline and two sites for the mesohaline sections of the Patuxent estuary.

Laboratory Analyses/Water Column Chemistry: Carl Zimmerman, Chesapeake Biological Lab, University of Maryland, Center for Environmental Science, Solomons, Maryland 20688-0038, [carlz@clb.umces.edu](mailto:carlz@clb.umces.edu), 410-326-7252.

**RESPONSIBILITIES:** This individual is responsible for total suspended solids and any nutrient analysis of water samples.

Chlorophyll Analyses/Water Column Chemistry: Asoka Katumuluwa, Chief, Division of Environmental Chemistry, Laboratory Administration, Maryland Department of Health and Mental Hygiene, [katumuluwaA@dhmh.state.md.us](mailto:katumuluwaA@dhmh.state.md.us), 410-767-5034.

**RESPONSIBILITIES:** This individual is responsible for administration of the chlorophyll and turbidity analysis of water samples.

Data Management: Chris Trumbauer/Bill Romano/Mark Trice/Christopher Heyer/Tyrone Lee/Tony Allred, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, 410-260-8630.

**RESPONSIBILITIES:** These individuals are responsible for overseeing the management of field and laboratory data collected under this program; managing historical field and laboratory data collected under this program; and maintaining existing data management software.

Data Analysis and Report Preparation: Mark Trice/Christopher Heyer/Bill Romano/Elizabeth Ebersole, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, 410-260-8630.

**RESPONSIBILITIES:** These individuals are responsible for statistical analyses, GIS mapping, and report preparation under this program.



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## Appendix 1. YSI 6600EDS Specification Sheet

### YSI 6600 EDS (Extended Deployment System)

Dissolved Oxygen % Saturation	Range Resolution Accuracy	0 to 500% 0.1% 0 to 200%: $\pm 2\%$ of reading or 2% air saturation, whichever is greater; 200 to 500%: $\pm 6\%$ of reading
Dissolved Oxygen mg/L	Range Resolution Accuracy	0 to 50 mg/L 0.01 mg/L 0 to 20 mg/L: $\pm 2\%$ of reading or 0.2 mg/L, whichever is greater; 20 to 50 mg/L: $\pm 6\%$ of reading
Conductivity †	Range Resolution Accuracy	0 to 100 mS/cm 0.001 to 0.1 mS/cm (range-dependent) $\pm 0.5\%$ of reading + 0.001 mS/cm
Temperature	Range Resolution Accuracy	-5 to +45°C 0.01°C $\pm 0.15^\circ\text{C}$
pH	Range Resolution Accuracy	0 to 14 units 0.01 unit $\pm 0.2$ unit
ORP	Range Resolution Accuracy	-999 to +999 mV 0.1 mV $\pm 20$ mV
Salinity	Range Resolution Accuracy	0 to 70 ppt 0.01 ppt $\pm 1\%$ of reading or 0.1 ppt, whichever is greater
Shallow Depth	Range Resolution Accuracy	0 to 30 feet (0 to 9 m) 0.001 feet (0.001 m) $\pm 0.06$ feet ( $\pm 0.02$ m)
Medium Depth	Range Resolution Accuracy	0 to 200 feet (0 to 61 m) 0.001 feet (0.001 m) $\pm 0.4$ feet ( $\pm 0.12$ m)
Deep Depth	Range Resolution Accuracy	0 to 656 feet (0 to 200 m) 0.001 feet (0.001 m) $\pm 1$ feet ( $\pm 0.3$ m)
Water Level	Range Resolution Accuracy	0 to 30 feet (0 to 9 m) 0.001 feet (0.0003 m) $\pm 0.01$ feet (0.003 m)
Turbidity	Range Resolution Accuracy Depth	0 to 1,000 NTU 0.1 NTU $\pm 5\%$ of reading or 2 NTU, whichever is greater 200 feet (60.96 m)
Chlorophyll	Range Resolution Depth	0 to 400 µg/L 0.1 µg/L, Chl: 0.1%FS 200 feet (60.96 m)
Rhodamine	Detection Limit Resolution Accuracy Depth	0.5 µg/L 0-200 µg/L, as true dye; 1,000 µg/L, as dye tracer $\pm 1$ µg/L, or $\pm 5\%$ reading 200 feet (60.96 m)

† Report outputs of specific conductance (conductivity corrected to 25°C), resistivity, and total dissolved solids are also provided. These values are automatically calculated from conductivity according to algorithms found in *Standard Methods for the Examination of Water and Wastewater* (ed 1989).

## Appendix 2. YSI 6600EDS Calibration and Post-Calibration Procedures

C. Trumbauer, J. Zimmerelli, C. DiBlasi

MD DNR

Revised March 2004

### I. SET UP

- A. Remove calibration cup, and set up the YSI with probes facing up.
- B. Trim the DO membrane with an x-acto knife, as closely as possible to the o-ring. Any extra pieces of the membrane hanging off may attract fish or crabs.
- C. Attach non-brushing wipers to the chlorophyll and turbidity probes. Always use an orange wiper for the chlorophyll probe and a white or gray wiper for the turbidity probe. Remember to align the screw on the wiper with the flat side of the probe post. Be sure the sponge portion is touching the probe firmly, but is not smashed down flat.
- D. Remove waterproof cap from the 9-pin sonde connector and attach sonde cable from laptop to sonde.
- E. Launch Ecowatch and select SONDE from the COMM menu. Choose COM 1 when prompted to select COM port.
- F. Type "reset" at the # prompt. (This resets wiper cycle.)
- G. Type "wprthresh" at the # prompt and press Enter. The program will then display the sensitivity of the optics. If it is not 40, then type "wprthresh 40".
- H. Next, type "menu" at the # prompt.
- I. Select STATUS, and then observe battery voltage. If voltage is less than 11 volts, replace batteries in the sonde. (You should also use this opportunity to clean battery compartment and grease figure eight O-ring with silica grease.)
- J. Return to main menu by pressing "0" or the ESC key. Select SYSTEM.
- K. Select DATE AND TIME, then TIME.
- L. Enter the correct time. (Obtain the time by dialing 410.844.1212 or consulting an atomic clock.)
- M. Return to main menu. Select REPORT.
- N. Select only the following parameters to be reported:  
Temp C, SpCond ms/cm, DO mg/l, pH, pH mV, Turbid NTU, Chl µg/L

### II. CHLOROPHYLL

- A. Prepare 0.5 mg/l Rhodamine WT solution from the stock solution (if needed.)
  - a. Retrieve 100 mg/l Rhodamine stock solution from refrigerator.
  - b. Warm to room temperature by placing in a warm water bath for 5 – 10 minutes.
  - c. Rinse clean 1000-ml volumetric flask 3 times with DI.
  - d. Fill 1000-ml volumetric halfway with DI water.
  - e. Using pipette bulb, rinse 5-ml volumetric pipette once with stock solution. Release rinse into sink **with water running** to allow waste to be flushed.
  - f. Pipette exactly 5.0 ml of the stock solution into 1000 ml volumetric flask using a volumetric pipette.
  - g. Dilute 1000 ml flask to the line with DI to form a 0.5 mg/l Rhodamine WT solution. Cap tightly, invert and swirl several times to homogenize.
  - h. Return stock solution to the refrigerator.
  - i. Rinse all waste in the sink and flush with plenty of water.

*NOTE: 0.5 mg/l solution is unstable, and must be used within 24 hours. Store solution in the dark.*

- B. Remove calibration cup from sonde and rinse probes with DI water.
- C. Fill a clean, dry calibration cup 3/4 full with DI water. Be sure to use a calibration cup with a black base. Place probes down into DI water allowing at least an inch between probes and the bottom of the calibration cup.
- D. Return to main menu. Select CALIBRATE, then OPTIC C - CHLOROPHYLL, then CHL  $\mu\text{G/L}$ , then TWO POINT. Enter zero (0) as the first standard.
- E. Press "3" to engage wipers. Note if wipers "park" 180° from the optical sensor. Check for air bubbles over optics. Repeat if necessary.
- F. After wipers have completed wiping cycle, allow readings to stabilize. Record chlorophyll blank concentration. Press enter, and record calibrated chlorophyll blank concentration.
- G. Rinse a clean, empty calibration cup, with a black base, 3 times, and then fill it ¾ full with the 0.5 mg/l Rhodamine solution
- H. Using lab thermometer, note temperature of Rhodamine standard.
- I. Place probes down into standard allowing at least an inch between probes and the bottom of the calibration cup.
- J. Using temperature reading obtained in step H, look up corresponding Chlorophyll value from Chlorophyll/Temperature chart in the folder. Enter this concentration (e.g. 113) as the second point in the calibration and press Enter.
- K. Press "3" to engage wipers again. Check for air bubbles over optics. Repeat if necessary.
- L. After wipers have completed wiping cycle, allow readings to stabilize. Record chlorophyll concentration and temperature. Press Enter, and record calibrated chlorophyll concentration.

### III. TURBIDITY

- A. Fill a clean, dry calibration cup 3/4 full with DI water. Be sure to use a calibration cup with a black base.
- B. Rinse probes with DI water and place sonde probes down into DI water allowing at least an inch between probes and the bottom of the calibration cup. Also, leave about 1.5 –2 inches of space between the top of the calibration cup and the threads on the sonde.
- C. Return to main menu. Select CALIBRATION, then TURBIDITY.
- D. Select 2 POINT. Enter the first standard as zero (0).
- E. Press "3" to engage wipers. Check for air bubbles over optics. Repeat if necessary.
- F. After wipers have completed wiping cycle, allow readings to stabilize. Record turbidity concentration. Press enter, and record calibrated turbidity concentration.
- G. Remove probes from DI water. Dry off Turbidity probe and temperature probe with a cotton swab or Kim-wipe. This will prevent the turbidity standard from becoming diluted.
- H. Gently fill a black-based calibration cup about 2/3 full with clean 123 NTU solution to minimize the amount of bubbles in the standard.
- I. Lower Turbidity probe down into calibration cup just enough to immerse tip of turbidity probe. There should be at least an inch between probe and bottom of the calibration cup, and also about 1.5 to 2 inches of space between the sonde and the top of the calibration cup.
- J. Enter second standard as 123.
- K. Press "3" to engage wipers. Note if wipers "park" 180° from the optical sensor. Check for air bubbles over optics. Repeat if necessary.
- L. After wipers have completed wiping cycle, allow readings to stabilize. Record turbidity concentration. Press enter, and record calibrated turbidity concentration.

#### IV. SPECIFIC CONDUCTANCE

- A. Attach open-ended calibration cup securely to sonde and rinse probes 3 times with DI water.
- B. Rinse probes 3 times with conductance standard to be used.
- C. Set sonde upright with probes facing up. Fill calibration cup with standard until the standard level is above conductivity block and temperature probe. If any air bubbles are apparent in the conductivity block, remove them by shaking sonde gently or dislodging them with a cotton swab.
- D. Select CONDUCTIVITY, then SPECIFIC CONDUCTANCE from the CALIBRATION menu.
- E. Enter the conductance of the standard in mS/cm. Example:  $294\ \mu\text{S} = 0.294\ \text{mS}$ .
- F. Press Enter when readings have stabilized. Record readings before and after calibration.
- G. Return to main menu.
- H. Select ADVANCED then CAL CONSTANTS. Record Conductivity Cell Constant.

#### V. pH

- A. With calibration cup securely attached to sonde, rinse probes 3 times with DI water.
- B. Rinse probes 3 times with pH 7 standard.
- C. Set sonde upright with probes facing up. Fill calibration cup with standard until the standard level is above pH and temperature probes.
- D. Return to main menu. Select CALIBRATION then PH, then 2-POINT.
- E. Enter 7, and allow at least 60 seconds for sonde to stabilize.
- F. When readings have stabilized press Enter, record pH before and after calibration, as well as the temperature and pH mV.
- G. Rinse probes 3 times with DI water.
- H. Rinse probes 3 times with pH 10 or pH 4 standard (depending on the expected pH of the waterway to be sampled)
- I. Fill calibration cup with standard until the standard level is above conductivity block and temperature probe.
- J. Enter 10 or 4 at prompt, and allow at least 60 seconds for sonde to achieve thermal equilibrium.
- K. When readings have stabilized press Enter, record pH before and after calibration, as well as the temperature and pH mV.
- L. Remove pH standard, and rinse probes with DI water.
- M. Now is a good time to remove the small turbidity wiper, and replace it with the large brush wiper that is used for deployment.

#### VI. DEPLOYMENT SET-UP

- A. Turn on the following parameters by selecting REPORT from the Main Menu: Date, Time, Temp, SpCond, Sal, DO%, DOmg/l, DOchrg, pH, Turb, Chl, Fluor, Batt.
- B. Return to main menu. Initiate data logging by selecting RUN, then UNATTENDED SAMPLE. Enter INTERVAL (15 minutes), START DATE, START TIME, DURATION (365 days), FILE and SITE. **Note:** START TIME should always be 59 seconds prior to a quarter-hour. For example: HH: 59:01, HH:14:01, HH:29:01, HH:44:01.
- C. Record File Name, Start Date/Time, Sampling Interval, Free Disk Space (in kb), and Battery Voltage in log book. If Battery voltage is less than 11 volts, change batteries. Make sure stop date is 1 year after start date.
- D. Exit menu back to # prompt and disconnect sonde cable.
- E. Screw on waterproof connector cap.

**VII. Dissolved Oxygen (Ideally performed day before deployment)**

- A. Closely observe DO membrane to ensure that it is free of water, scratches, and nicks. Remove any water carefully with cotton swab. If scratch or nick is apparent, DO membrane must be replaced.
- B. Wipe dry the metal thermistor – a wet thermistor can indicate an artificially low temperature reading due to evaporation.
- C. Place probe guard onto instrument, being careful of the DO membrane, and exposed pH probe.
- D. Wrap moist towel around the probe-end of the instrument to create a saturated-air environment.
- E. Place instrument in a cooler that is cracked open to allow it to be in equilibrium with the atmosphere.
- F. Allow air to become water saturated and sonde to come to thermal equilibrium (at least 30 minutes.)
- G. After enough time has elapsed, select *CALIBRATE* from the main menu, and then *DISSOLVED OXYGEN*.
- H. Next choose DO SAT%. Take current Barometric Pressure from a reliable barometer in the room. Log in Barometric Pressure in mm Hg and press <Enter>.
- I. Sonde will automatically perform calibration. Record barometric pressure, temperature, sonde DO before and after calibration, DO Sat% before and after calibration, and true DO value, as calculated from pressure/temperature chart. **Record DO charge.** If DO charge <25 or >75, DO probe needs to be serviced.
- J. Return to main menu. Select *ADVANCED* then *CAL CONSTANTS*. Record DO Gain.

**VII. Dissolved Oxygen Check (performed the morning of the deployment)**

- A. Verify DO calibration by connecting sonde cable to sonde, accessing menu and selecting *VIEW FILES* then *QUICK VIEW*. Note the most recent several samples, and check that the readings are stable.
- B. Record the temperature, DO (mg/L), DO %, DO charge
- C. Check the barometric pressure, and record the true DO from the temperature/pressure chart.
- D. If samples are consistent and accurate within 0.2 mg/L of true DO value according to chart, do not recalibrate sonde.
- E. If samples are not within 0.2 mg/L of true DO, recalibrate sonde according to *step VII-H*. Since the sonde is already in a saturated air environment, you need not wait for equilibrium. Record changes in calibration log.
- F. If samples are greater than 0.5 mg/L of true DO, do not recalibrate and do not deploy instrument until DO issue is resolved.

**Post Calibration**

**IX. Notes**

- A. During Post Calibration, the idea is to preserve the condition of the sonde after deployment. Thus it is important *not* to clean sonde or remove any fouling that may have been deposited.
- B. Because most sondes will exhibit biological fouling or sediment buildup on the probes after a deployment, they will tend to contaminate any standards with which they come in contact. Therefore, a second set of “dirty” standards are used to perform post calibrations.
- C. Clean standards are typically rotated into “dirty” standards at the end of each field week. When the “dirty” standards become significantly contaminated with biological material



or dirt, they should be discarded and replaced with the clean standards. New, clean standards are then prepared.

- D. From the main menu, select REPORT. Select only the following to be reported:  
Temp C, SpCond ms/cm, DO mg/l, pH, pH mV, Turbid NTU, Chl µg/L

**X. Dissolved Oxygen** (ideally performed the day after retrieving sonde)

- A. If sonde was wrapped in moist towel following retrieval, make sure membrane and thermistor are dry, keep towel on sonde and allow sonde to come to thermal equilibrium in a stable environment – usually overnight. Allow sonde to continue to log data while coming to equilibrium. Connect sonde cable to sonde and access last several readings according to *step VII-H in the Calibration procedures*. Skip to step C.
- B. If there was a problem - sonde malfunction, batteries died, etc. - you may run a post calibration by accessing menu, selecting RUN, then DISCREET SAMPLE using a sample interval of 120 sec.
- C. Check barometric pressure using reliable barometer.
- E. Record temperature, barometric pressure, DO (mg/l), DO Sat%, and DO Charge.
- F. Also record true D.O. as read from temperature and pressure chart. If the D.O. is more than 0.5 mg/L off from the chart D.O. reading, make a large note on the post calibration sheet.
- G. Stop logging by selecting RUN, UNATTENDED SAMPLE, then STOP LOGGING.
- H. At this time, upload the data from the last deployment. In the main menu, select FILE, then QUICK UPLOAD.
- I. Select PC6000, and press enter. This will automatically upload the most recent deployment data onto the computer. It will be stored under the folder, Ecowatch.
- J. After uploading the latest data set from the YSI, remove the towel and probe guard from the sonde.
- K. Remove the EDS “clean-sweep” or brush wiper from the turbidity probe, and replace with a small gray or white non-brushing wiper. Place the EDS brush wiper in a beaker with water and light soap to soak.
- L. The sonde is now ready to complete the post-calibration process, or it can be stored in a calibration cup with DI until the post-calibration can be completed.

**XI. CHLOROPHYLL AND TURBIDITY**

- A. Do not rinse probes.
- B. Fill a clean, dry calibration cup  $\frac{3}{4}$  full with DI water. Be sure to use a calibration cup with a black base.
- C. Place probes down into DI water allowing at least an inch between probes and the bottom of the calibration cup.
- D. Select RUN from the main menu. Select DISCREET SAMPLE.
- E. Change SAMPLE INTERVAL to 4 seconds.
- F. Select START SAMPLING. Wipers should activate. If not, press “3” to activate wipers manually. Observe if wipers park 180° from optic sensors. Note this in log book.
- G. Place and hold lab thermometer in DI water until temperature reading is stable. Record thermometer temperature in logbook.
- H. After wipers have completed cycle, record instrument temperature, chlorophyll zero and turbidity zero readings once they have stabilized.
- I. Remove probes from DI water and *carefully* dry tips of turbidity and chlorophyll probes including wiper with Kim-wipe or cotton swab. Do not clean off the optic sensors. *Note:* Turbidity standard is particularly fragile so try to minimize contamination by cleaning tip of turbidity probe. This should not affect reading *as long as the optical sensor is not*



*cleaned.*

- J. Fill a clean black-based calibration cup 2/3 full with "dirty" 123 NTU solution.
- K. Lower probes down into calibration cup just enough to immerse the tips. There should be at least an inch between probe and bottom of the calibration cup. Also allow about 1.5 to 2 inches of space between the top of the calibration cup and the bottom of threading on the sonde.
- L. Press "3" to engage wipers.
- M. After wipers have completed wiping cycle, record turbidity reading when readings have stabilized.
- N. Fill a clean, dry calibration cup ¾ full with the 0.5 mg/L Rhodamine solution (see section 2). Be sure to use a calibration cup with a black base. Place probes down into DI water allowing at least an inch between probes and the bottom of the calibration cup.
- O. Press "3" to engage wipers.
- P. After wipers have completed wiping cycle, allow readings to stabilize. Record chlorophyll concentration and temperature.

## **XII. Specific Conductance**

- A. Attach open-ended calibration cup securely to sonde.
- B. **Gently** rinse probes 3 times with conductance standard that was used to calibrate the sonde. Take care not to dislodge fouling from conductance block, as the goal is to read conductance "as is."
- C. Set sonde upright with probes facing up. Fill calibration cup with "dirty" conductance standard until the standard level is above conductivity block and temperature probe. Pour standard gently down the side of calibration cup to prevent dislodging dirt or growth from probes. If any air bubbles are apparent in the conductivity block, remove them by shaking sonde gently or dislodging them with a cotton swab.
- D. Run a DISCREET SAMPLE with SAMPLE INTERVAL of 4 seconds.
- E. Record conductance when readings have stabilized.

## **XIII. pH**

- A. With calibration cup securely attached to sonde, **gently** rinse probes 3 times with DI water, taking care not to dislodge any fouling from the pH probe.
- B. Gently rinse probes 3 times with pH 7 buffer.
- C. Set sonde upright with probes facing up. Gently pour standard down the inside of the calibration cup until the buffer level is above pH and temperature probes.
- D. Run a DISCREET SAMPLE with SAMPLE INTERVAL of 4 seconds.
- E. Allow at least 30 seconds for sonde to stabilize.
- F. When readings have stabilized, record pH, pH mV and temperature.
- G. Gently rinse probes 3 times with DI water.
- H. Gently rinse probes 3 times with pH 10 or pH 4 buffer (use whichever buffer used to calibrate instrument.)
- I. Gently pour pH 10/pH 4 buffer down the inside of the calibration cup until the standard level is above pH and temperature probes.
- J. Run a DISCREET SAMPLE with SAMPLE INTERVAL of 4 seconds.
- K. Allow at least 60 seconds for sonde to stabilize.
- L. When readings have stabilized, record pH, pH mV and temperature.

***Sonde should now be cleaned and stored for next deployment.***

### Appendix 3. Continuous Monitoring and Water Quality Mapping Filtering Methods

#### A. Particulate sample filtration, processing and storage

##### 1. Chlorophyll

Chlorophyll samples are filtered in the same manner for all programs.

- a) For every depth sampled, clean a 47mm bell with deionized (DI) water. Set up unit for filtering. Be sure that there is a trap in line between the manifold and the vacuum source.
- b) Place a Whatman 47mm GF/F glass fiber filter pad (pore size = 0.7  $\mu$ m) on the filter frit. Always use clean forceps when handling the filter pads.
- c) Mix sample thoroughly by agitating and shaking the sample bottle vigorously, then rinse graduated cylinder three times with sample.
- d) Agitate the sample again before measuring in the graduated cylinder. Fill graduated cylinder with sample and filter desired volume through filtration unit. Be sure to use a graduate that is close to the volume being filtered (ex: if you are only filtering 80 ml of sample use a 100 ml graduate). Keep the vacuum pressure below 10 inches of Hg (around 8" Hg is good).
- e) Filter sufficient volume of sample (50 - 1500 ml) to solidly color the filter pad.
- f) Record the total volume filtered on the foil square.
- g) Agitate the squirt bottle of  $\text{MgCO}_3$ , as it settles rapidly. Add approximately 1 ml of  $\text{MgCO}_3$  suspension (1.0 g  $\text{MgCO}_3$  in 100 ml of DI water) to the last 25 ml of sample in the filtration bell.

*NOTE: Samples for dissolved parameters are not to be collected from this filtrate.*

- h) Using forceps (1 or 2 pair), fold filter in half with sample inside and remove filter pad.
- i) Place pad in pre-marked foil square, and carefully fold foil square in thirds, horizontally. Then fold the ends in to seal the filter inside. Be sure forceps do not touch sample residue on the filter pads, because the sample will adhere to the forceps. When filtering chlorophyll for core samples, after you fold the filter in half, fold in half again to make it  $\frac{1}{4}$  size so it will fit in the small zip-lock bag neatly.
- j) Be sure that foil square is marked with date, station, depth of sample, volume of sample filtered, and sample number. For core samples, be sure the baggie is labeled with the station number, date and volume filtered.
- k) Place foil packet into zip-lock plastic bag or pad container. When sampling on the small boats or a land run place the foils in a bag or pad container in the ice chest and place them in the appropriately labeled bag in the Field Office freezer when you return to the office. The bags for the chlorophyll samples go in the bin marked DHMH in the freezer.
- l) Record sample station number, date, volume filtered (L), depth (m), layer, start time, end time and field scientist sign-off on the chlorophyll volume sheet. Record the study code, submitter code, data category code and replicate number, if not already pre-filled in, on chlorophyll volume sheet. This sheet is submitted to the laboratory with the samples. When you return the samples to the Field Office freezer, place the volume sheet in the rack on the side of the freezer marked "Chlorophyll, DHMH".

*NOTE: The filter pads for chlorophyll samples should be exposed to as little direct sunlight as possible. Store as soon as possible.*

##### 2. Particulate Carbon/ Particulate Nitrogen (PC/PN)

PC/PN samples are filtered in the same manner for all programs.

- a) Follow steps A.1.a. through A.1.d. above setting up two 25 mm filter bells using two

- pre-combusted 25 mm GF/F filters (pore size = 0.7  $\mu$ m). The PC/PN pads come from CBL.
- b) Filter 10-200 ml through each filter. Filter enough sample to leave noticeable color on the filter pad.
  - c) Make sure filter is sucked dry and the same volume is filtered for both pads.
  - d) Record the volume filtered (total volume through one pad - do not add the volumes for the 2 pads together) on the foil square.

*NOTE: Samples for dissolved parameters are not to be collected from this filtrate.*

- e) Using forceps, fold each filter in half.
  - f) Place both filters in a foil square labeled with date, CBL sample number, station, sample layer, PC/PN, and volume filtered. Be sure that the pads are not overlapping in the foil square to keep them from freezing together.
  - g) Fold the foil square as described in step A.1.i. above and then place folded foil in zip-lock bag or pad container, and put in the freezer (large boats) or in a cooler on ice (small boats & land).
  - h) Upon return to the Field Office, place the foils in their appropriate zip-lock bag in the sample freezer and place the bag in the CBL bin. Put the completed CBL volume sheet in the rack on the side of the freezer marked "CBL".
3. Particulate Phosphorus/ Particulate Inorganic Phosphorus (PP/PIP)
- a) Follow steps A.1.a. through A.1.d. above setting up and rinsing two 47 mm filter bells and flasks. The filters used are two Whatman 47 mm GF/F filters (same pads we use for chlorophyll).
  - b) Filter 50 ml of sample through each filter pad.
  - c) Use the filtrate as an equipment rinse and discard.
  - d) Then filter enough additional (another 50 - 450 ml) to leave a noticeable color on the filter pad.
  - e) Record the total volume filtered through each pad being sure to add the 50 ml rinse water (total volume through one pad – do not add the volumes for the 2 pads together) on the foil square.
  - f) Use this filtrate to fill up the tubes for the dissolved parameter analysis. See section C (Filtered dissolved nutrient sample collection) below.
  - g) After collecting filtrate, make sure filter is sucked dry.
  - h) Rinse the filter pad using at least three - 10 ml rinses of DI water, sucking the pad dry after each rinse.
  - i) Using forceps, fold each filter in half.
  - j) Place both filters in a foil square labeled with date, PP/PIP, CBL sample number, station, sample layer, and volume filtered (this is the total volume of sample through each pad, including the initial 50 ml rinse). Be sure that the pads are not overlapping in the foil square to keep them from freezing together.
  - k) Fold the foil square as described in step A.1.i. above. Place foil square in zip-lock bag or pad container, and put in the cooler on ice until you return to the field office.
  - l) Upon return to the Field Office, place the foils in their appropriate zip-lock bag in the sample freezer and place the bag in the CBL bin. Put the completed CBL volume sheet in the rack on the side of the freezer marked "CBL".
4. Total Suspended Solids/ Volatile Suspended Solids (TSS/VSS)
- The instructions below apply to samples processed for TSS/VSS for Dataflow and Continuous Monitoring programs.

- a) Follow steps A.1.a. through A.1.d. above setting up and rinsing one 47 mm filter bell and flask. The filter used is a pre-combusted and pre-weighed 47 mm GF/F filters (pore size = 0.7  $\mu$ m). The VSS pads come in individually numbered petri dishes from CBL. Remove one pad from its individual petri dish and place on the filter screen. Record the pad number from the petri dish on the TSS/VSS foil label in the space marked "Pad #".
- b) Filter 50 - 500 ml and filter through the filter pad leaving a noticeable color on the pad.
- c) Make sure filter is sucked dry and rinse the filter pad using at least three - 10 ml rinses of DI water, sucking the pad dry after each rinse. If the sample is very salty (e.g. Lower Chesapeake, Coastal Bays) you should rinse an extra 1-2 times.

*NOTE: Samples for dissolved parameters are not to be collected from this filtrate.*

- d) Using forceps, fold the filter in half. Place the filter in a foil square labeled with date, TSS/VSS, CBL sample number, station, sample layer, and volume filtered, and VSS pad number.
- e) Fold the foil square as described in step A.1.i. above. Place foil square in zip-lock bag or pad container, and put in the cooler on ice until you return to the field office.
- f) Upon return to the Field Office, place the foils in their appropriate zip-lock bag in the sample freezer and place the bag in the CBL bin. Put the completed CBL volume sheet in the rack on the side of the freezer marked "CBL".

#### B. Dissolved nutrient sample filtration & collection

*NOTE: The filtrate collected for this sample must come from either the TSS/PP or PP/PIP filtration set-up. If you cannot get enough water through these pads to fill all tubes, then use plain GF/F filters to get enough filtrate. The filtrate may not come pads that are pre-combusted (PC/PN & VSS) or units that are in contact with  $\text{MgCO}_3$  (CHLA).*

1. The following steps are to be completed for collection of all filtrate for the samples below:
  - a) Run 50 ml of sample water through the filter.
  - b) Use this 50 ml of filtrate to rinse the flask and then discard.
  - c) Run more sample water through the filter and collect in the flask.
2. Total Dissolved Nitrogen & Phosphorus (TDN/TDP)
  - a) Rinse the TDN/P tube (30 ml borosilicate glass – tall skinny tube!) and cap three times with filtrate.
  - b) Flick all remaining water droplets out of the test tube and cap.
  - c) Rinse the 10 ml graduated cylinder three times with filtrate.
  - d) Fill the graduated cylinder with 10 ml of filtrate.
  - e) Carefully, pour the 10 ml of filtrate into the test tube and cap tightly.
  - f) Store the test tube in the freezer.
  - g) If on a land run or small boat, store the tubes on ice in a cooler and place in the Field Office freezer when you return from the field.
3. Nitrate, Nitrite, Ammonia, Orthophosphate & Silicate
  - a) Rinse the 4 like-numbered AA vials (4 ml polystyrene cups) and 4 caps three times with filtrate.
  - b) Fill the AA vials with filtrate up to ridge where the caps are seated.
  - c) Snap the caps on the vials. You should hear them snap twice to be fully seated.
  - d) Store 3 AA vials in the freezer. Store 1 AA vial in the refrigerator.

- e) If on a land run or small boat, store the tubes on ice in a cooler and place in the Field Office freezer and refrigerator when you return from the field.
4. Dissolved Organic Carbon (DOC)
- a) Rinse the DOC tube (30 ml Teflon) and cap three times with filtrate.

#### **Appendix 4. Photosynthetic Active Radiation Protocol - May 15, 2003**

##### **Underwater Photosynthetically Active Radiation (PAR, 400-700nm)**

Down welling light penetrating the water column (PAR) is measured underwater at several depths to calculate the light attenuation coefficient,  $K_d$ . Simultaneous deck and submersed PAR intensity measurements are taken to account for variability in incident surface irradiance due to changes in cloud cover. Data collected from this procedure may be used to estimate the depth of the photic zone.

1) Equipment: Manufactured by LI-COR, Inc.

- 2) LI-192SA, flat cosine Underwater Quantum Sensor
- 3) LI-190SA air (deck) reference sensor.
- 4) Data Logger (LI-1000 or LI-1400)

2) Parameters:

1. EPARU\_Z      Downwelling PAR, measured underwater with sensor pointed up.  
( $\mu\text{M}$ , micromoles/second-meter<sup>2</sup> =  $\mu\text{E}$ , microEinsteins)
2. EPAR\_S      PAR measured in air, on board vessel or pier, recorded concurrently with each underwater depth reading ( $\mu\text{M}$ )
3. SDEPTH      Sample depth at which PAR reading is recorded (meters)

3) Procedure:

1. PAR is determined from the sunny (or unshaded) side of a vessel or pier during daylight hours. Both deck and submersed probes must be away from the shadow of the vessel.
2. Check the sensor operation by connecting the deck sensor and underwater sensor to corresponding ports of the Li-Cor data logger, and turn the power on. Check battery level. Cover the sensor and check to see if the output is very near zero. Place the sensor under a light source to assure that it has a positive reading. A negative reading indicates that the polarity of the sensor is reversed, and is plugged into the cable backwards. A very positive or negative reading in the dark indicates a possible short in the cable or some other electrical short.

In the field, mount the deck sensor in a location which is level and unobstructed by shadows. Ensure that sensors are positioned properly on the deck sensor mounting and the lowering frame. Connect deck sensor and underwater sensor to corresponding ports of the sonde, and turn the power on.

3. Set instrument averaging constant to display results from previous 10 or 15 seconds.
4. Lower the frame until the sensor is just below the surface of the water. At a depth of 0.1 meter (~ 4 inches), simultaneously record the deck sensor and the underwater readings for the "surface" measurement. If wave action prevents this, take the initial reading at 0.5 meters. Depth of the underwater sensor diffuser below the surface of the water is determined with a calibrated pole or non-stretching rope.

5. Lower the frame and take subsequent measurements at depths appropriate to the monitoring location and purpose of the project (see below). Allow the instrument output to stabilize, at least for the averaging period, then record both deck and underwater readings at each depth.

The simultaneous deck and submersed readings are stored by pressing "Enter". Each record will be stored with a time stamp which will flash on the data logger readout. Record this time. All readings can be subsequently retrieved at the end of the cruise.

1. Mainstem and Tidal Tributary Photic Zone

When taking light attenuation profiles in mid-channel stations, record sub-surface PAR at a depth of 0.5 meter below the surface. Collect subsequent measurements at depths according to the clarity of the water, as determined by the Secchi measurement. The following table should be utilized:

Secchi	Depth Interval (in addition to 0.1 meter)
0-0.3	0.25 meter
0.4-0.6	0.5
0.7-1.9	1.0
2.0-2.9	2.0*
3.0 and greater	3.0*

\*Collect light at 1, 2 and 3 meters and then start alternating the depth.

Measurements are recorded until the sonde reads <10 % of the initial subsurface value, or if the bottom is reached.

2. Shallow Water Monitoring (Data Flow and Fixed Continuous Monitors)

Light attenuation profiles are performed in shallow waters for SAV habitat assessment. The following procedure is prescribed for correlating  $K_d$  with in-vivo turbidity data (i.e., from water quality mapping and fixed continuous monitors). Record initial PAR at a depth of 0.1 meter below the surface. When depth to bottom is less than 2 meters, record 2 to 3 additional PAR measurements at 0.25, 0.5 and 1.0 meters. When depth to bottom exceeds 2 meters, record PAR at 5 depths (e.g., 0.1, 0.5, 1.0, 1.5 and 2.0 meters).

- 4) Quality control

1. The deck cell should have the highest PAR value, and the underwater sensor output should decrease as the sensor is lowered.
2. Periodically check that sensors are linear and not out of calibration with respect to each other.
3. PAR sensors should be returned to LICOR, Inc. every year, prior to each field season.
4. Replicate PAR profiles are recommended to make sure readings are correct.
5. Reporting

Report the PAR values from the deck sensor and each underwater measurement under the following CIMS data base method codes:

1. EPARU\_Z F01: Flat cosine sensor LI-192SA
2. EPAR\_S F01: Deck (reference) sensor LI-190SA
3. SDEPTH: Sample depth at which PAR reading is recorded, in meters

#### 5) Light Attenuation ( $K_d$ ) Calculations

To calculate the light attenuation coefficient ( $K_d$ ), adjust each underwater PAR value by multiplying by the ratio of:

$$\frac{\text{Maximum EPAR}_S \text{ in profile}}{\text{EPAR}_S \text{ from that DEPTH}}$$

Using adjusted PAR values, calculate  $K_d$  by one of the methods below.

- 1) Correlation Coefficient: Plot the natural log of each adjusted PAR value on the x-axis vs. depth, in meters. The slope of the line times (-1) is  $K_d$ ; the y-intercept is the depth of the photic zone.

Raw data for this calculation can be retrieved from the CIMS Data Hub. Under CBP Water Quality Database, “click to get data” and select the “Light Attenuation Data”.

- 2) SAV 2-point Method: Calculate  $K_d$  from the (adjusted) PAR values from two different depths according to the equation:

$$K_d = - \left( \frac{\ln(\text{adjusted PAR deep}) - \ln(\text{adjusted PAR shallow})}{(\text{Deep Depth} - \text{Shallow Depth})} \right), \quad \text{or}$$

$$K_d = \frac{\ln \text{ adjusted PAR deep/adjusted PAR shallow}}{\Delta \text{ Depth (m)}}$$

Calculated  $K_d$  using this method can be retrieved from the CIMS Data Hub (<http://www.chesapeakebay.net>). Under CBP Water Quality Database, “click to get data”, then select “Water Quality Data”. CIMS calculates  $K_d$  based on the SAV 2-point method and automatically adjusts the underwater values if air sensor values are present for each depth. PAR values are taken between the most consistent, shallowest, underwater depths and as close to 1 meter below the surface that is available. In most tributary mid-channels the calculator will select values from Depths = 0.1 and 1.0 meters. In Maryland mainstem, values are usually from Depths = 0.5 and 1.5 meters; in Virginia mainstem,  $K_d$  data are calculated with Depths = 1.0 and 2.0 meters.

The CIMS  $K_d$  calculator will not calculate  $K_d$  for any sampling event with only one PAR reading in the first 2 meters of the water column, or if underwater PAR values are negative.





## **Appendix 5. Maryland Department of Health and Mental Hygiene Method for Turbidity Analysis**

### **Turbidity EPA Method 180.1 (Nephelometric)**

#### **1.0 SCOPE AND APPLICATION**

- 1.1 This method is applicable to drinking, ground, waste and saline waters.
- 1.2 The applicable range is 0 to 4000 nephelometric turbidity units (NTU). Higher values may be determined with dilution of the sample.

#### **2.0 SUMMARY OF METHOD**

- 2.1 The method is based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension. The higher the intensity of light scattered, the higher the turbidity. Readings in NTUs are made in a Nephelometer designed according to specifications outlined under Equipment and Supplies.
- 2.2 A set of commercially available polymer primary standards with a concentration range from 20 to 4000 NTU is used to calibrate the instrument once every two months. These standard solutions are identified as AMCO CLEAR, available from Advanced Polymer Systems and are EPA approved.
- 2.3 Another set of above polymer primary standards with a concentration range from 0.5 to 20 NTU is used as a daily calibration check.

#### **3.0 INTERFERENCES**

- 3.1 The presence of floating debris and coarse sediments which settle out rapidly will give low readings. Air bubbles will affect the results in a positive manner.
- 3.2 The presence of true color, that is, the color of water which is due to dissolved substances, which absorb light, will cause turbidity values to be low, although this effect is generally not significant with drinking waters.
- 3.3 Light absorbing materials such as activated carbon in significant concentrations can cause low readings.

#### **4.0 HEALTH AND SAFETY**

- 4.1 Good laboratory practices should be followed during inversion of sample, handling of silicone oil (may cause eye irritation; do not ingest) and reading of sample result.

#### **5.0 EQUIPMENT AND SUPPLIES**

##### **5.1 Equipment**

- 5.1.1 Hach Model 2100AN Laboratory Turbidimeter B The turbidimeter consists of a nephelometer with a tungsten-filament lamp for illuminating the sample. Detectors are in place to measure the 90° light scatter, the forward scattered light, the back scattered light and the light transmitted through the sample. The instrument microprocessor uses a

mathematical calculation to ratio signals from each detector. The benefits of applying ratio on measurements include better linearity, calibration stability, wide measurement range, and the ability to measure turbidity in the presence of color.

## **5.2 Supplies**

5.2.1 Sample cells, 30 ml capacity; Hach catalogue number 20849-00.

## **6.0 REAGENTS AND STANDARDS**

### **6.1 Reagents**

6.1.1 Distilled water with a turbidity reading of less than 0.07 NTU.

### **6.2 Standards**

6.2.1 A set of Primary Standards consisting of turbidity values 0, 20, 200, 1000 and 4000 NTU is used to calibrate the instrument once every two months.

6.2.2 A set of standards with turbidity values 0, 0.5, 2.0, 5.0, 20, 50, 100, and 200 NTU is used for daily calibration of the instrument.

## **7.0 SAMPLE COLLECTION, PRESERVATION, AND STORAGE**

7.1 Samples are collected in liter polyethylene cubitainers. Samples should be refrigerated or iced to 4°C until analysis to minimize microbiological decomposition of solids. The holding time is 48 hours when preserved at 4°C.

## **8.0 QUALITY CONTROL**

8.1 AMCO CLEAR primary standards with concentrations ranging from 0.5 to 200 NTU are analyzed before each day's run of samples. The instrument calibration is considered valid when the each measured NTU value is within 90 B 110% of its true value. The daily calibration curve is considered acceptable when the coefficient of correlation of the calibration curve is equal to or greater than 0.9950.

8.2 Every tenth sample is analyzed in duplicate. The accepted value for the relative standard deviation (RSD) is 10 %.

8.3 A blank (distilled water) is run at the beginning and after every ten samples. The accepted value for the blank is less than 0.07 NTU.

8.4 A commercially available quality control sample is analyzed quarterly.

## **9.0 PROCEDURE**

### **9.1 Sample Cell Preparation**

#### **9.1.1 Use of Samples Cells**

9.1.1.1 Samples cells should be clean and free of fingerprints; any water droplets on the outside surface should be wiped dry. A light coating of silicone oil applied to the outside surface and then wiped to attain an even film will minimize the effects of minor scratches or other imperfections in the glass. The oil coating also helps to eliminate static electricity on the sample cell, which tends to collect dust. Sample cells that are nicked or scratched extensively must be replaced. Because imperfections in the glass cause variations between sample cells, best accuracy will be obtained if the same cell is used when doing comparisons among samples or when calibrating the instrument. Also accuracy is increased if the sample cell is oriented the same way in the cell holder every time. An index mark appears on each 25 mm cell for this purpose; it should be aligned with the raised mark on the spill ring around the cell holder opening. All cells should be marked likewise.

9.1.1.2 The fill ring on the sample cell represents a volume of approximately 30 mL. It is recommended that the cell be filled to the mark every time to ensure that the volume is well beyond the minimum amount required.

### **9.2 Instrument Calibration**

#### **9.2.1 Instrument Start-up**

Leave the turbidimeter on 24 hours a day if the instrument is used regularly. Make sure Ratio, Sample and Signal Average keys are in ON mode displayed by a green light. Maintain Range key in auto mode. Select NTU from Units/Exit key.

#### **9.2.2 Calibration with Primary Standards (once every two months)**

##### **9.2.2.1 Press Cal Zero**

9.2.2.2 Insert 0 NTU standard, press Enter; wait as the display counts down, then continue entering the rest of the standards in increasing sequence.

9.2.2.3 Press Cal Zero again to store calibration information into memory.

### **9.3 Sample Analysis**

9.3.1 Prepare the list of samples for turbidity on the sample run sheet starting with blank, the daily calibration standards of 0.5, 2.0, 5.0, 20, 50, 100, and 200 NTU, the distilled water, then followed by each sample number. Measure one replicate, one check standard and one blank for every ten samples.

9.3.2 Fill the clean and dry glass cell with distilled water. Insert the cell. If the reading is greater than 0.07 NTU, the cell should be cleaned with detergent and the process be repeated. Distilled water should have an NTU value of less than 0.07. Press Enter & Print to send data to computer. Continue entering the daily calibration standards in the increasing sequence.

9.3.3 If readings of standards are not within 10% of the true values, and standards are less than one year old, the turbidimeter should be recalibrated.

9.3.4 Allow samples to reach room temperature to prevent fogging of the cell. Thoroughly mix the sample by gentle inversion. Do not shake. Quickly remove cap and pour approximately 20 mL of sample into the cell for rinse. Immediately fill cell with sample to volume line, wipe dry and insert into turbidimeter. Align the index mark on the cell with the raised mark on the spill ring around the cell holder opening. Be sure the cell has been pushed down completely and is held in place by the spring clip. Cover the sample with the light shield.

9.3.5 Read the turbidity of the sample from the digital display. Press Enter & then press Print to save the first stable reading at approximately 15 seconds. If the turbidity reading fluctuates up and down, take the cell out, invert to mix well and measure again. Observe the results in the display for accuracy. After every tenth sample, measure one standard with the concentration within the range of the sample readings.

9.3.6 After reading all samples, double click the blank area outside the table to go to Microsoft Excel. Enter all sample identifications according to the run sheet into the sample column. Display the daily calibration curve with r-square value. Save the date as the file name. Print out the results along with the daily calibration curve.

## **10.0 DATA ANALYSIS AND CALCULATIONS**

10.1 Multiply sample reading by the dilution factor to obtain the final reading.

10.2 Report results to tenths of an NTU when using the 0-20 range and report whole numbers when the value is above 20 NTU.

## **11.0 DATA AND RECORDS MANAGEMENT**

11.1 The detection limit for this method is 0.5 NTU. All sample concentrations below this value are recorded as less than 0.5 NTU (< 0.5 NTU).

11.2 All daily run sheets are kept in a binder labeled as "Turbidity". All quality control data are kept in a binder labeled as "Quality Control".

## **12.0 WASTE MANAGEMENT**

12.1 Samples and standards are poured down the drain while flushing with large amount of cold water.

## **13.0 REFERENCES**

13.1 United States Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes. Method Number 180.1 Revision 2.0 August 1993

13.2 Hach Instruction Manual for Model 2100AN Laboratory Turbidimeter With Software Version 1. 1993

- 13.3 The ABC's of NTU's B A Primer on Turbidity B J. A. Spair. Available from Advance Polymer Systems B 3696 Haven Avenue, Redwood City, California 94063

## Appendix 6. Nutrient Analytical Services Laboratory / Chesapeake Biological Laboratory Method for Total Volatile Solids Analysis

### TOTAL VOLATILE SUSPENDED SOLIDS Revised 2/2004

Total volatile solids (TVS) is the volatilized material that is lost on ignition from Total Suspended Solids (TSS). It is calculated from the measurement of a total suspended solid (TSS) sample minus the measurement of the quantity remaining after combustion. Results are expressed in mg/L.

#### Methodology

APHA. 1975. Method 208 E (with modification). Total volatile and fixed residue at 550° C. in Standard Methods for the Examination of Water and Wastewater, 14<sup>th</sup> Edition. American Public Health Association. Washington, D.C. 1193pp.

#### Sample Collection and Handling

1. Combust Whatman 47 mm GF/F filters (0.7 µm pore size) in an oven set at 500° C for 90 minutes. This setting on CBL's oven has been determined to be 550° C.
2. Weigh filters (g) to 4 decimal places to obtain pre-weight and store individual pads in a numbered petri dish.
3. Follow sample filtration procedure for total suspended solid sample. Make note of pad number on foil pouch.

#### Procedure

1. Dry filters overnight at 103°-105° C. Allow to cool to room temperature in dessicator.
2. Weigh filters and record weights (in g). Calculate TSS.
3. Transfer filter to a porcelain crucible and combust at 500° C for 90 minutes. Allow to cool to room temperature in dessicator.
4. Weigh filter and record weights (in g). Calculate TVS.

#### Calculation of TVS

$$mgTVS / L = \frac{(W_{combust(g)} - W_{post(g)}) \times 1000}{V_L}$$

where:  $W_{combust}$  = dry weight of filter pad and sample after combustion (in grams).  
 $W_{post}$  = dry weight of filter pad after filtering (in grams).  
 $V_L$  = volume of water filtered (L)

## **Appendix 7. Continuous Monitoring Procedures**

*C. Trumbauer, J. Zimmerelli*

Revised: 1/7/2004

### **Installation:**

- To collect seamless continuous data, two instruments are needed for each site. Deploy the first instrument at the site for a week. At the end of the week, replace this instrument with the second instrument. During the next week, post-calibrate and clean the first instrument and prepare it to be deployed the next week.
- Use a 4" diameter PVC pipe to install a site. The length depends on the depth of the selected site.
- Coat the PVC pipe with an effective anti-fouling paint to prevent biological contamination.
- Drill 2" holes down the length of the PVC pipe that will typically lie below the water line to allow water to pass through the tube.
- Attach the tube to a wooden 2x4 using two copper or stainless steel clevis hangers. Then attach the 2x4 to a piling or pier using lag bolts.
- Place a chain through the tube, and lock it with a combination or key lock to prevent theft or vandalism.

### **Calibration:**

- Calibrate each instrument using laboratory quality standards directly prior to each deployment (see Appendix 4).
- Synchronize the internal clock in the instrument and all watches with the official time. The official time is available by calling 410-844-1212. A radio-controlled clock that automatically synchronizes to the Atomic Clock in Boulder, CO can also be used.

### **Deployment:**

- Deploy the instrument at a fixed site at a regular interval, e.g., weekly or bi-weekly.
- Record the date, location, weather conditions, tide, time of deployment, and initials on the calibration log.
- Leave the instrument that was deployed the prior week in place inside the PVC tube while suspending the freshly calibrated instrument at the same depth, right next to the old one. Allow both instruments to take at least one simultaneous reading in order to compare the data from the two instruments. This comparison is used during QA/QC process to ensure both instruments were taking accurate measurements
- Use a Hydrolab (or similar) instrument with a display unit to take an additional simultaneous reading. The real-time display makes it possible to note any sudden fluctuations or trends in the water quality parameters.
- At exact time of sample reading, take a grab sample using a Kemmerer type apparatus suspended at the same depth as the sondes.

### **Sample Processing :**

- Grab sample is filtered immediately after it is taken. Sample is filtered according to Chesapeake Bay Program protocol (see Appendix 2).
- Processed sample is iced down in the field, and frozen in a freezer upon return to the field office. It is then sent to lab for analysis at the end of the week via courier.



**Water Column Profile:**

Water column profiles should be taken at each continuous monitoring station when the YSI 6600 EDS sondes are being replaced. This profile will be done with the check instrument (e.g., Hydrolab) and will measure the following parameters:

- Depth
- Water Temperature (°C)
- pH
- Specific Conductance (µmhos/cm)
- Dissolved Oxygen (mg/l)
- Salinity (ppt)

There should be NO layer code associated with these additional measurements.

The following procedure should be followed for the profile:

For sondes that are fixed above the bottom:

1. Lower the check instrument (e.g., Hydrolab) to the deployed sonde depth and record that reading as the three-way *in situ* match-up reading (e.g., the QH or QY layer).
2. If there is adequate depth, take a second reading at 1 meter below the surface.
3. Take a final reading at 0.5 meter below the surface.

*Note: The depth tolerance shall be 0.2 meters. If your sonde depth is within 0.2 meters of a profile stop, then you can skip that profile stop (e.g., If your sonde is fixed at 0.5 meter above the bottom and the water column depth at the sonde is 1.7 meters, then you would skip the profile reading at 1 m and just take readings at the sonde and 0.5 meter below the surface.).*

For sondes that are floating below the surface:

1. Lower the check instrument (e.g., Hydrolab) to the deployed sonde depth and record that reading as the three-way *in situ* match-up reading (e.g., the QH or QY layer).
2. If there is adequate depth and the reading would be below the deployed sonde depth, take a second reading at 0.3 meter above the bottom.
3. Take a final reading at 0.5 meter below the surface.

**Retrieval:**

- After both instruments have been allowed to take at least one simultaneous reading, remove the old instrument.
- Record the date, location, weather conditions, tide, time of retrieval, and initials on the calibration log.
- Brush out the instrument tube with a Webster-type brush, on the inside and outside.
- Deploy the fresh instrument in its place.
- Wrap the old instrument in a damp towel and take it back to the lab for post-calibration and cleaning.

**Post-calibration/cleaning:**

- Post-calibrate each retrieved instrument against laboratory standards to ensure that it was taking accurate measurements. Preferably complete this post-calibration the day after the instrument is retrieved, allowing the instrument to equilibrate to standard temperature and pressure overnight in 100% saturated air environment before conducting the post-calibration. If field staff are unable to

calibrate the instrument the day after retrieval, ensure that the instrument is post-calibrated by the second day after retrieval.

- After completion of post-calibration, thoroughly clean each instrument and prepare it for re-deployment the following week.

## **Appendix 8. Water Quality Mapping Procedures**

*W. Nelson*

Revised: 3/12/2004

### **Water Quality Mapping Procedures**

The following procedures should be followed when collecting data for the DATAFLOW project.

#### Cruise tracks:

Cruise tracks will vary from one tributary to the next depending on its size and shape, and navigational hazards, but will either follow a 6ft. contour along each shore, or a “square wave” pattern traversing from shallow water to deeper water over the length of the tributary; stopping at 6 calibration stations.

#### Calibration stations:

At each calibration station collect a physical profile using a Hydro lab, collect a whole water sample for CBL nutrients and DHMH chlorophyll filtering, collect a 16 oz. whole water sample for turbidity, and a PAR profile using a LiCor.

#### Hydrolab profile:

Collect the 0.5 m readings first. Record the exact minute that the 0.5 m readings are collected as the start time. You must also simultaneously collect the whole water sample for Chlorophyll and Nutrient analysis at this time. Then lower the sonde to the bottom and take readings 0.3 m above the bottom and every 0.5 m or 1.0 m intervals to the surface depending on the total depth (see below).

#### If total depth is < 3 m.:

Hydrolab readings will be collected at 0.5 m from the surface and at 0.5 m intervals, and 0.3 m above the bottom.

#### If total depth is 3 m. or > than 3 m.:

Hydrolab readings will be collected at 0.5 m from the surface and at 1.0 m intervals, and 0.3 m above the bottom.

Whole water samples will be collected from the outflow of the DATAFLOW unit. Collection must be done simultaneously with the 0.5 m Hydrolab readings. A numbered 2 qt. bottle will be rinsed 3 times and filled to be used for CBL nutrient samples and a DHMH chlorophyll sample. A labeled 16 oz. bottle will also be rinsed and filled simultaneously with the 2-quart bottle to be submitted to DHMH for turbidity analysis. All whole water and processed samples will be immediately placed on ice until delivery to the office or courier.

As conditions permit, CBL nutrient and DHMH chlorophyll filtering will begin as soon as possible. Filtrate will be collected from the PP units only. In addition to standard filtrate samples, 2 PP (unnumbered Whatman) pads, 1 VSS/TSS (numbered) pad, 2 PC/PN pads, and 1 chlorophyll (unnumbered Whatman) pad will be submitted for analysis.

### **Water Quality Mapping LiCor Procedures**

LiCor readings will be collected from the sunny side of the boat; both deck (out of water) and underwater readings will be recorded simultaneously. Allow readings to stabilize before recording data. This normally takes several seconds.

If the total depth is < 3 m:

Record both deck and underwater readings at 0.10m and at 0.25m intervals until 10 % of first underwater reading is reached. \*\*

If the total depth is equal to or > 3 m:

Record both deck and underwater readings at 0.10m and at 0.5m intervals until 10% of first underwater reading is reached.

\*\* If depth is < 0.5m make sure to record at least 3 different depth readings.

Example: If total depth is 0.25m record data from 0.05m, 0.10m and 0.20m

# Appendix 9. Example of Continuous Monitoring Instrument Calibration and Comparison Table

Deployment:	STP0342 (KAYLA)						
Post Calibration							
D.O.			Optics			pH	
Temperature	20.41	deg C	Chl. zero =	0.9	ug/l	pH 7 =	6.93
Bar. Pressure	751	mm Hg	Chl. Std.	116.0	ug/l	dev	0.07
Chart D.O.	8.91	mg/l	Meter Reads	120.5	ug/l	mV	-32.4
Meter D.O.	9.12	mg/l	Chl. dev	4.5	ug/l	pH 10 =	9.91
D.O. Dev.	0.21	mg/l				dev	0.09
D.O. Sat	101.1	%	Turb. zero =	3.3	NTU	mV	-212.0
			Turb. Std.	100.0	NTU		
Sp. Cond.			Meter Reads	98.3	NTU	Temp	
Standard	2767	uS/cm	Turb. dev	1.7	NTU	Thermometer	20.54
Meter Reads	2787	uS/cm				Meter Reads	20.58
Dev	20	uS/cm				dev	0.04
Meter Comparison Tables							
10/14/2003	Old YSI	New YSI	D	Discrete	D		
Meter	Tess	Kayla		C			
Time	14:00	14:00		14:00			
Temp (* C)	18.52	18.53	0.01	18.53	0.00		
Sp. Cond. (mS/cm)	4321	4399	78	4450	51		
D.O. (mg/l)	10.69	11.33	0.64	10.46	0.87		
pH	8.63	8.37	0.26	8.63	0.26		
Turbidity (NTU)	5.3	9.0	3.7	6.5	2.5	from lab	
Chlorophyll (mg/l)	16.4	14.7	1.7				
10/21/2003	Old YSI	New YSI	D	Discrete	D		
Meter	Kayla	Tess		F			
Time	8:15	8:15		8:15			
Temp (* C)	15.26	15.25	0.01	15.19	0.07		
Sp. Cond. (mS/cm)	4543	4472	71	4480	63		
D.O. (mg/l)	9.57	9.31	0.26	9.31	0.26		
pH	7.38	7.58	0.20	7.52	0.14		
Turbidity (NTU)	13.6	4.8	8.8	9.2	4.4	from lab	
Chlorophyll (mg/l)	13.1	13.2	0.1				

# Appendix 10. YSI 6600EDS Calibration Log

YSI 6600 CALIBRATION LOG				METER		PAGE #	
<b>CALIBRATION</b>				<b>POST CALIBRATION</b>			
Date		Time		Date		Time	
Location				Location			
Deployment site:			RESET? Y N				
Initials			Zero Depth? Y N	Initials			
<b>Dissolved Oxygen</b>				<b>Dissolved Oxygen</b>			
DO Membrane changed: (date / initials):				Stopped Logging?	YES NO	Upload?	YES NO
Temperature		°C		Temperature		°C	
Bar. Pressure		mm Hg		Bar. Pressure		mm Hg	
Chart D.O.		mg/L		Chart D.O.		mg/L	
Meter D.O.		mg/L		Meter D.O.		mg/L	
changed to		mg/L		D.O. Saturation		%	
D.O. Saturation		%		D.O. Charge			
changed to		%		Thermometer temp		°C	YSI temp: °C
D.O. Charge		(Range 25 to 75)		Chlorophyll (2-point)			
D.O. Gain		(Range 0.8 - 1.7)		Chlorophyll zero		µg/L	
Chlorophyll (2-point)				Temperature		°C	
Chlorophyll zero		µg/L		Chlorophyll Std		µg/L	
Temperature		°C		Meter reads		µg/L	
Rhodo WT equivalent		µg/L		Wiper parks 180 deg. from sensor?			YES NO
Meter reads		µg/L		Turbidity (2-point)			
Wiper parks 180 deg. from sensor?		YES NO		Turb zero		NTU	
Turb zero		NTU		Turb Std		NTU	
Turb Std		NTU		Meter reads		NTU	
Meter reads		NTU		Wiper parks 180 deg. from sensor?			YES NO
changed to		NTU		Specific Conductance			
Wiper parks 180 deg. from sensor?		YES NO		Sp. Cond. Std.		µS/cm	
Sp. Cond. Std.		µS/cm		Meter reads		µS/cm	
Meter reads		µS/cm		Temperature		°C	
changed to		µS/cm		Meter pH			
Cond. Cell Const.		(Range 4.6 - 5.45)		pH mV		mV	
Temperature		°C		Temperature		°C	
Meter pH reads				Meter pH			
changed to				pH mV		mV	
pH mV		mV (Range 0 ± 50)		Battery		changed	YES NO
Temperature		°C		<b>DATA SET COMPARISON</b>			
Meter pH				old	new	Discrete	
changed to				meter			
pH mV		mV (Range -180 ± 50)		time			
<b>PROGRAMMING</b>				<b>PROGRAMMING</b>			
Parameters: (circle)	Date Time Temp	SpC Sal	DO% DO Chl pH	Temp.			°C
Set time to:	EST	Turb Chl Fluor Batt	Sp. Cond	Salinity			µS/cm
Log to filename			D.O.				ppt
Start Date / Time / interval	/	/ min	pH				mg/l
Started Logging	YES	NO	Turb.				NTU
Free Disk Space	kilobytes		Chloro				µg/L
Battery	Volts	changed Y N	total depth =	m	secchi =	m	
<b>FIELD DATA</b>				<b>FIELD DATA</b>			
Date	Time		DO Check				
Weather	Yesterday:		/ / 04				
Clouds	%		Temp				
Wind	kts Direction:		B.P.				
Waves	m		Chart				
Tide			Meter				
Initials			DO %				
Add'l Samples?	Turb Walt		Charge				
			Re-Cal? Y N				

## Appendix 11. Continuous Monitoring Parameters

C. Trumbauer, C. Heyer, M. Trice

Revised: 1/7/2004

Parameter	Format/Units	Field Name	Method Code
Date	mmddyyyy	SAMPLE_DATE	
Time	hh:mm:ss (24 hr clock – EST)	SAMPLE_TIME	
Station		STATION	
Tributary		WATER_BODY	
Segment		CBSEG_2003	
Sonde (YSI Sonde Name)	Variable Length (e.g. “Gina” or Serial Number)	SONDE	
Latitude	Decimal Degrees (NAD83)	LATITUDE	
Longitude	Decimal Degrees (NAD83)	LONGITUDE	
Sample Depth Value	meters (+)	SAMPLE_DEPTH*	
Sample Depth Reference	BS = Floating Below Surface AB = Fixed Above Bottom VP = Vertical Profile	LAYER_CODE*	
Water Column Depth	meters (+)	TOTAL_DEPTH**	
Battery Voltage	volts	BATT	
Water Temperature	°C	WTEMP	F01
Specific Conductance	ms/cm	SPCOND	
Salinity (From YSI Sonde)	ppt	SALINITY	F01
Dissolved Oxygen Saturation	%	DO_SAT	F01
Dissolved Oxygen Concentration	mg/l	DO	F01
pH	su	PH	F01
Turbidity	NTU	TURB_NTU	F01 for 6136 F02 for 6026
Fluorescence	% FS (FS = Full Scale)	FLUOR	
Pre-calibrated Total Chlorophyll	µg/l	TCHL_PRE_CAL	
Post-calibrated Chlorophyll <i>a</i>	µg/l	CHLA	

\* The SAMPLE\_DEPTH should always be used in conjunction with the LAYER\_CODE for descriptive information on where the sonde is located in the water column.

\*\* The TOTAL\_DEPTH only applies to fixed depth sonde and is adjusted to account for the distance the sonde is fixed above the bottom.

**Appendix 12. Water Quality Mapping Parameters***C. Trumbauer, C. Heyer, M. Trice*

Revised: 1/7/2004

Parameter	Format/Units	Field Name	Method Code
Date	mmddyyyy	SAMPLE_DATE	
Time	hh:mm:ss (24 hr clock – EST)	SAMPLE_TIME	
Cruise Track	AAAmddyyyy (AAA = 3 Letter Trib Code)	STATION	
Tributary		WATER_BODY	
Primary Segment		PRI_SEG	
Sonde (YSI Sonde Name)	Variable Length (e.g. "Gina" or Serial Number)	SONDE	
Latitude	Decimal Degrees (NAD83)	LATITUDE	
Longitude	Decimal Degrees (NAD83)	LONGITUDE	
Sample Depth Value	meters (+)	SAMPLE_DEPTH*	
Sample Depth Code	BS = Floating Below Surface AB = Fixed Above Bottom VP = Vertical Profile	LAYER_CODE*	
Water Column Depth	meters (+)	TOTAL_DEPTH	
Boat Speed	knots	BOAT_SPEED	
Battery Voltage	volts	BATT	
Water Temperature	°C	WTEMP	F01
Specific Conductance	ms/cm	SPCOND	
Salinity (From YSI Sonde)	ppt	SALINITY	F01
Dissolved Oxygen Saturation	%	DO_SAT	F01
Dissolved Oxygen Concentration	mg/l	DO	F01
pH	su	PH	F01
Turbidity	NTU	TURB_NTU	F01 for 6136 F02 for 6026
Fluorescence	% FS (FS = Full Scale)	FLUOR	
Pre-calibrated Total Chlorophyll	µg/l	TCHL_PRE_CAL	
Post-calibrated Chlorophyll <i>a</i>	µg/l	CHLA	

\* The SAMPLE\_DEPTH should always be used in conjunction with the LAYER\_CODE for descriptive information on where the sonde is located in the water column.



### Appendix 13. Continuous Monitoring and Water Quality Mapping Error Codes

C. Trumbauer, C. Heyer, M. Trice

Revised: 2/23/2004

Category	Code	Description	Immediate Data Impacts	Suggested Uses
Specific Probe Codes	PSW	Salinity Calibrated at the Wrong Level	Data Invalid - Hide Data Value	
Specific Probe Codes	PDP	DO Poisoning (Anoxia)	Data Invalid - Hide Data Value	Membrane Degraded Due to Low DO
General Probe Codes	GBO	Blocked Optic	Data Invalid - Hide Data Value	Extreme Single-Point Turbidity and Chlorophyll Spikes
General Probe Codes	GWM	Wiper Malfunction	Data Invalid - Hide Data Value	Evident Biofouling on Optics
General Probe Codes	GWL	Wiper Lost	Data Invalid - Hide Data Value	
General Probe Codes	GSC	Seal Compromised	Data Invalid - Hide Data Value	
General Probe Codes	GPF	Probe Failure	Data Invalid - Hide Data Value	
General Probe Codes	GPC	Post Calibration Out of Range	Data Invalid - Hide Data Value	
General Probe Codes	GNV	Negative Value	Data Invalid - Hide Data Value	
Non-Probe Codes	NPF	Power Failure	Data Invalid - Hide Data Value	
Non-Probe Codes	NOW	Instrument Out of the Water	Data Invalid - Hide Data Value	
Non-Probe Codes	NNF	Ram Clogged / No Flow	Data Invalid - Hide Data Value	Water Quality Mapping Specific
Non-Probe Codes	NND	No Data	Data Invalid - Hide Data Value	Missing Data Values
Non-Probe Codes	NIS	Invalid Data Due To Incorrect YSI Setup	Data Invalid - Hide Data Value	
Non-Probe Codes	NIR	Instrument Removed	Data Invalid - Hide Data Value	Instrument Removed from Water for Short Duration (Within a Deployment)
Non-Probe Codes	NQR	Data Rejected Due To QA/QC Checks	Data Invalid - Hide Data Value	

Category	Code	Description	Immediate Data Impacts	Suggested Uses
Comments	CTS	Time Skip	Comment - No Impact on Data Value	Improper Time Recording By Sonde
Comments	CBF	Biofouling	Comment - No Impact on Data Value	
Comments	CWD	Instrument at Wrong Depth (Depth Value)	Comment - No Impact on Data Value	Continuous Monitoring Specific
Comments	CTF	Temperature Probe Failure	Comment - No Impact on Data Value	
Comments	CSW	Salinity Calibrated at the Wrong Level	Comment - No Impact on Data Value	
Comments	CLF	Flow Low	Comment - No Impact on Data Value	Water Quality Mapping Specific
Comments	CDB	Disturbed Bottom	Comment - No Impact on Data Value	Field Observation
Comments	CTC	Time Change	Comment - No Impact on Data Value	NA to Data Post 2003
Comments	CTW	Turbid Water	Comment - No Impact on Data Value	Field Observation
Comments	CFK	Fish Kill	Comment - No Impact on Data Value	Field Observation
Comments	CSC	Site Location Change	Comment - No Impact on Data Value	Continuous Monitoring Specific
Comments	CAS	Algal Sample Taken (Sample #)	Comment - No Impact on Data Value	Field Observation
Comments	CAB	Algal Bloom - No Sample Taken	Comment - No Impact on Data Value	Field Observation

#### **Appendix 14. Continuous Monitoring Data Verification and Management Procedures**

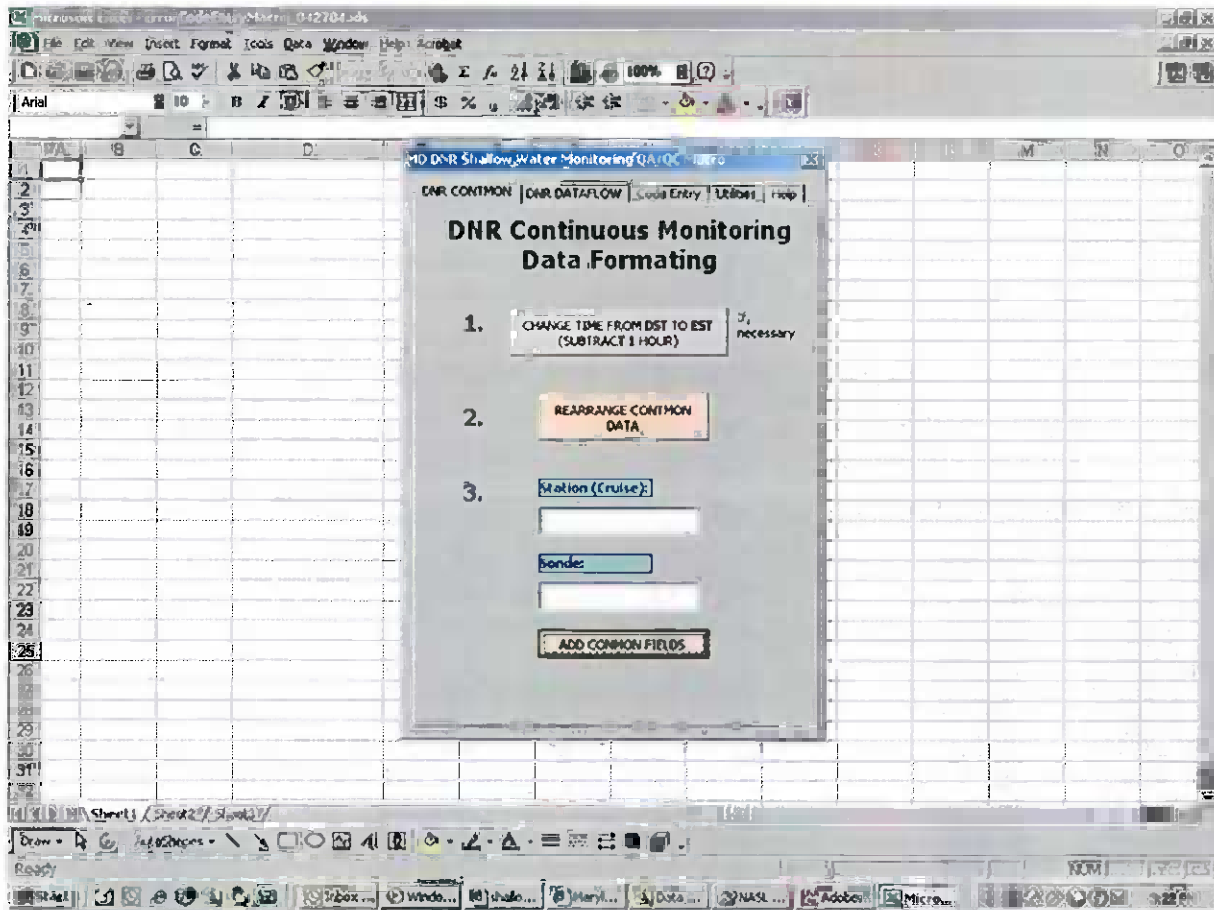
*C. Trumbauer, C. Heyer, M. Trice*

*Revised: 5/24/2004*

- 1) Open raw .DAT file in Ecowatch and rearrange parameters into the following order:  
DATE, TIME, BATT, DEPTH, TEMP, SP.COND, SALINITY, DO%, DOCONC, PH, TURBIDITY, CHL, FLUOR
- 2) Using the file naming convention of the station three-letter designation followed by the two-digit year and the two-digit week, export files from Ecowatch in .CDF format (e.g., STP0418.cdf).
- 3) Using Microsoft Excel, open the .CDF file, choosing comma delimited when prompted to identify the delimiter type.
- 4) Delete all data that were taken when the sonde was not in the water on station (i.e., transit time from the field office to the station). Use the logbooks to determine this time.
- 5) Run the QA/QC macro by clicking the "REARRANGE CONTMON DATA" button on the "DNR CONTMON" tab of the macro dialog (Figure A14\_1). When this button is clicked, the existing data columns are rearranged, new data columns are added, and error code columns are added. Error code fields are designated by the suffix "\_A". The columns are ordered as follows:

SAMPLE\_DATE  
SAMPLE\_TIME  
STATION  
SONDE  
TOTAL\_DEPTH  
TOTAL\_DEPTH\_A  
BATT  
BATT\_A  
WTEMP  
WTEMP\_A  
SPCOND  
SPCOND\_A  
SALINITY  
SALINITY\_A  
DO\_SAT  
DO\_SAT\_A  
DO  
DO\_A  
PH  
PH\_A  
TURB\_NTU  
TURB\_NTU\_A  
FLUOR  
FLUOR\_A  
TCHL\_PRE\_CAL  
TCHL\_PRE\_CAL\_A  
CHLA  
CHLA\_A  
COMMENTS

- 6) Examine the data from the previous deployment, if applicable, and delete any overlapping data records resulting from the three-way *in situ* match-up. The overlapping record should be deleted from this deployment to ensure that the data are continuous from deployment to deployment.

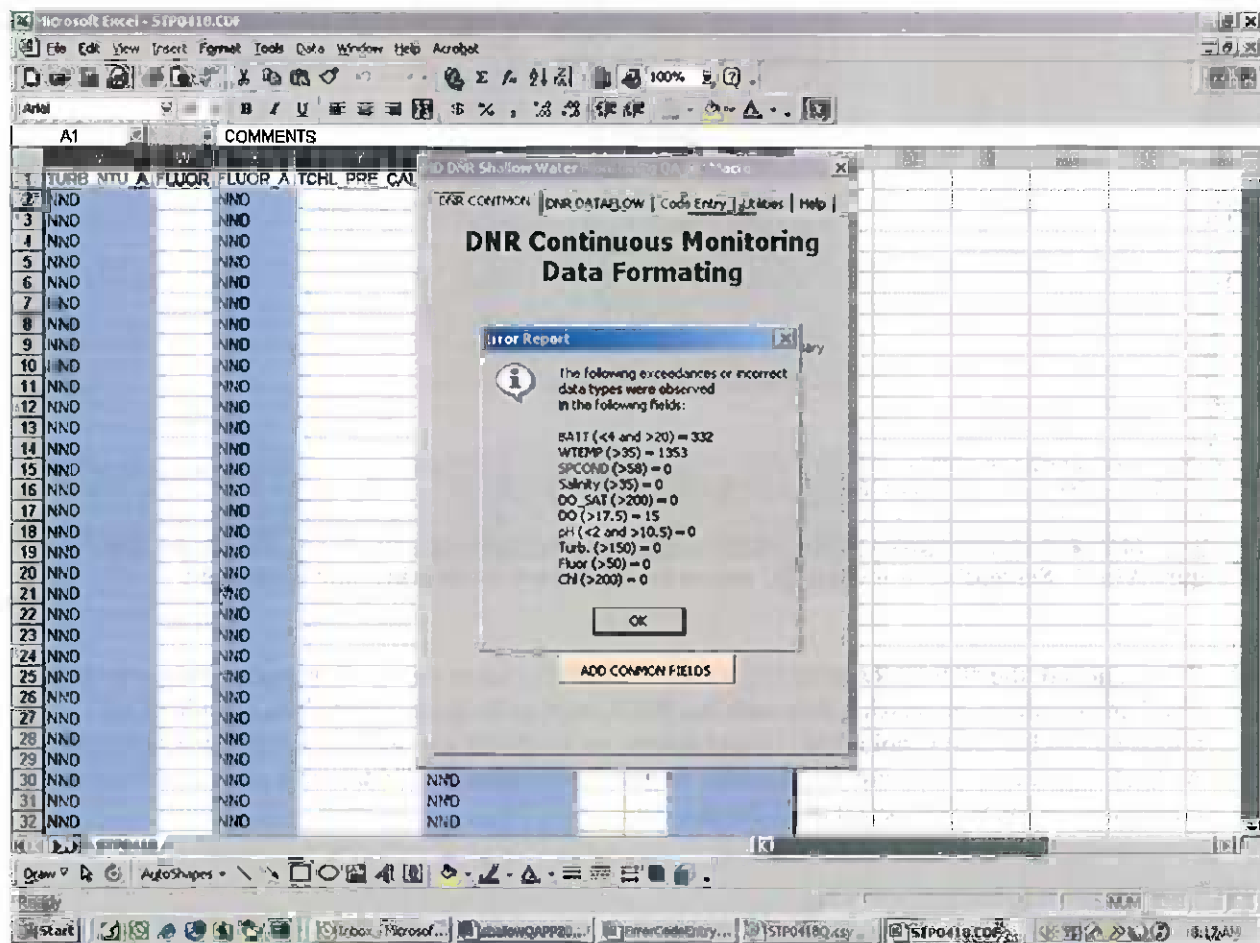


**Figure A14\_1. Screenshot of the QA/QC macro for continuous monitoring data formatting.**

- 7) When clicked, the “REARRANGE CONTMON DATA” button also flags negative values with the GNV error code, flags missing data with the NND error code, highlights values outside of set tolerance levels in red (Table A14\_1), and returns an overview summary of exceedances (Figure A14\_2). Tolerance levels are purposefully large to accommodate the diversity of data collected throughout Maryland’s Coastal and Chesapeake Bays.

**Table A14\_1. Tolerance levels automatically checked by the QA/QC macro.**

Parameter	Tolerance
BATT	<4 and >20
WTEMP	>35
SPCOND	>50
Salinity	>35
DO SAT	>200
DO	>17.5
PH	<2 and >10.5
TURB	>150
FLUOR	>50
TCHL_PRE_CAL	>200



**Figure A14\_2. Screenshot of exceeded tolerances.**

- 8) Enter the Station and Sonde information for the deployment being reviewed into the macro dialog box and click "ADD COMMON FIELDS". This inserts the station name and sonde name into each record.

9) Flagging Values with the QA/QC Macro:

Sound data management practices dictate that data should never be deleted. As such, we employ a data management system in which all original data values are retained in the database, but erroneous data are masked with an error code (see Appendix 13 for list of error codes). Each parameter value field also has an error code field associated with it and is designated with the suffix “\_A” (e.g., DO\_A). Error codes should only be written to the error code fields. Comments should only be written to the COMMENTS field. Because the data file is comma separated, a comma should never be used to separate comments in the COMMENTS field; a semi-colon can be used instead. The following steps outline how the QA/QC Macro can be used to insert error codes and comments.

- a) Go to the “CODE ENTRY” tab of the QA/QC macro to access all of the tools necessary to enter error codes and comments in selected cells (Figure A14\_3).
- b) Use the “SELECT CELLS” box to select the cells of the spreadsheet in which you want to enter error codes or comments.
- c) After the cells have been selected, choose a “PREDEFINED CODE” or “CUSTOM CODE” by selecting the appropriate button.

*NOTE: Custom codes should only be used for comments. They should never be used for error codes because the database only recognizes predefined error codes.*

- d) Select either a “PROBE SPECIFIC”, “GENERAL PROBE”, “NON-PROBE” or “COMMENTS” code by clicking the appropriate radio button, or if applicable, type in a custom comment.
- e) Select the appropriate code and click the “ENTER CODE” button.
- f) Repeat Steps b-e as necessary.

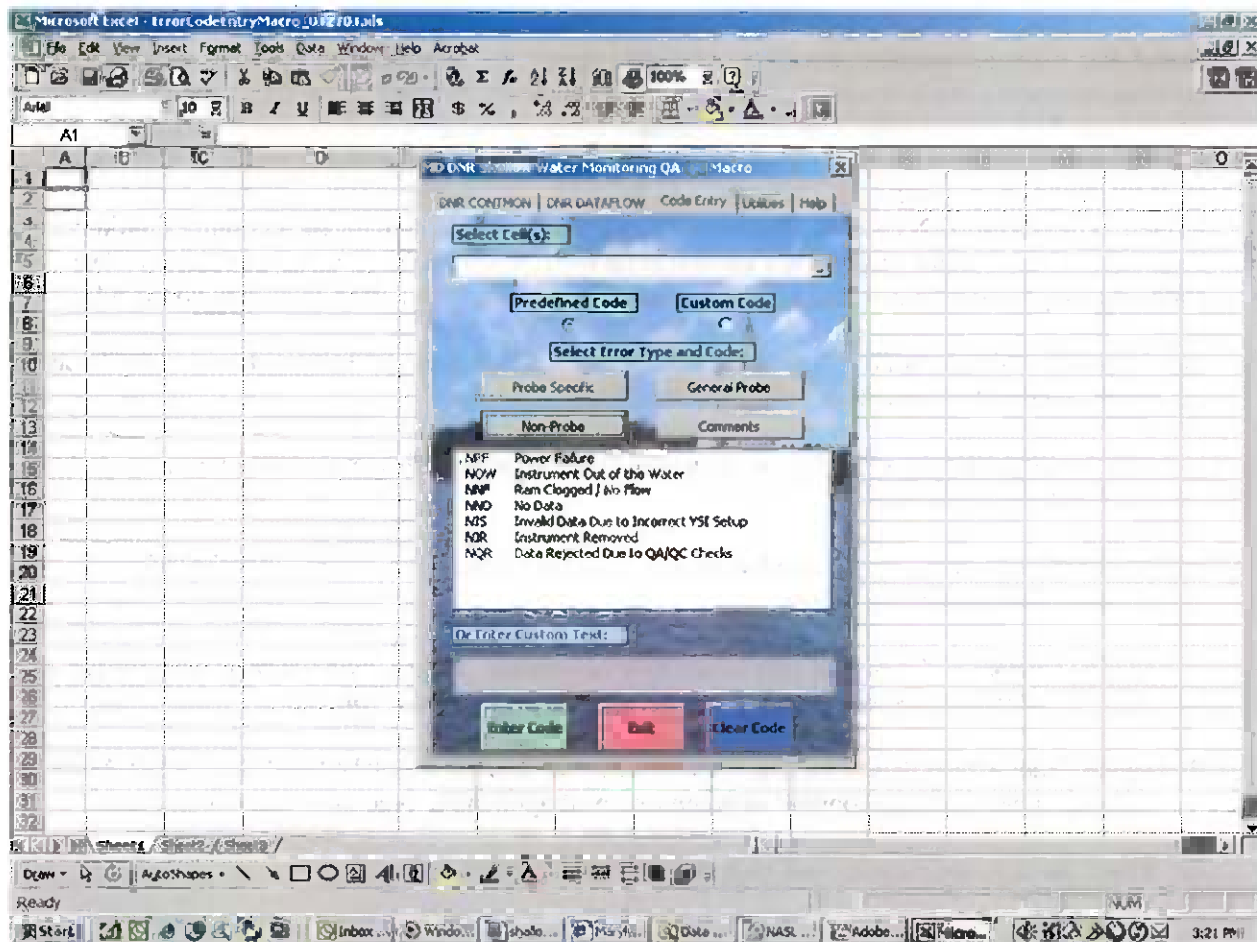


Figure A14\_3. Screenshot of QA/QC macro's code entry screen.

- 10) Using the procedures outlined above in Step 8 to flag data, identify any suspicious data by inspecting the values flagged in red and the original data graphed in Ecowatch. Common anomalies include abnormal spikes in chlorophyll and turbidity, abnormal dips in specific conductance, and abnormally high dissolved oxygen readings due to high dissolved oxygen charge. Post-calibration and *in-situ* field checks should also be used to identify when probes are reading incorrectly.

**NOTE:** *Do not be too quick to flag data. Flagging data is necessary to remove obvious outliers from the data set. Strange things can and do occur in Maryland waters, and we do not want to flag an anomaly just because it seems out of place. Anomalies should be identified, but must not be flagged unless there is proper justification. If you feel a period of data is questionable, but should not be excluded, keep it unflagged in the data set, but mention it in the comments field.*

- 11) Once all of the error codes and comments have been entered into the data file, close the macro and save the file as a Comma Separated Value (.CSV) file using the same naming convention as above with a "Q" added to the end (e.g., STP0418Q.csv).

The resulting .CSV file can then be imported into DNR's database. The QA/QC'd data can also be posted to the Eyes on the Bay ([www.eyesonthebay.net](http://www.eyesonthebay.net)) website to overwrite any existing provisional real-time data.

There should be three files when a data set is complete. In our example, these files would be:  
STP0418.dat (Raw data - no editing),  
STP0418.cdf (Exported file with travel time deleted), and  
STP0418Q.csv (Final QA/QC'd file with erroneous data masked)





## **Appendix 15. Water Quality Mapping Data Verification and Management Procedures**

*C. Trumbauer, C. Heyer, M. Trice*

*Revised: 5/24/2004*

- 1) Open raw .txt file created by DATAFLOW / Labview Software in Excel
- 2) Use the file naming convention of the segment three-letter designation followed by the two-digit month, the two-digit day and the four-digit year and save the raw data file
- 3) Delete all data that were taken when the boat was docked at the start and end of the cruise. Remove all data that has no associated GPS coordinate data, or data that are instrument error codes or 'garbage' characters.
- 4) Run the QA/QC macro by clicking the "REARRANGE DATAFLOW DATA" button on the "DNR DATAFLOW" tab of the macro dialog (Figure A15\_1). When this button is clicked, the existing data columns are rearranged, new data columns are added, and error code columns are added. Error code fields are designated by the suffix "\_A". The columns are ordered as follows:

SAMPLE\_DATE  
SAMPLE\_TIME  
STATION  
WATER\_BODY  
PRI\_SEG  
SONDE  
LATITUDE  
LONGITUDE  
TOTAL\_DEPTH  
TOTAL\_DEPTH\_A  
BOAT\_SPEED  
BOAT\_SPEED\_A  
BATT  
BATT\_A  
WTEMP  
WTEMP\_A  
SPCOND  
SPCOND\_A  
SALINITY  
SALINITY\_A  
DO\_SAT  
DO\_SAT\_A  
DO  
DO\_A  
PH  
PH\_A  
TURB\_NTU  
TURB\_NTU\_A  
FLUOR  
FLUOR\_A  
TCHL\_PRE\_CAL  
TCHL\_PRE\_CAL\_A

CHLA  
CHLA\_A  
COMMENTS

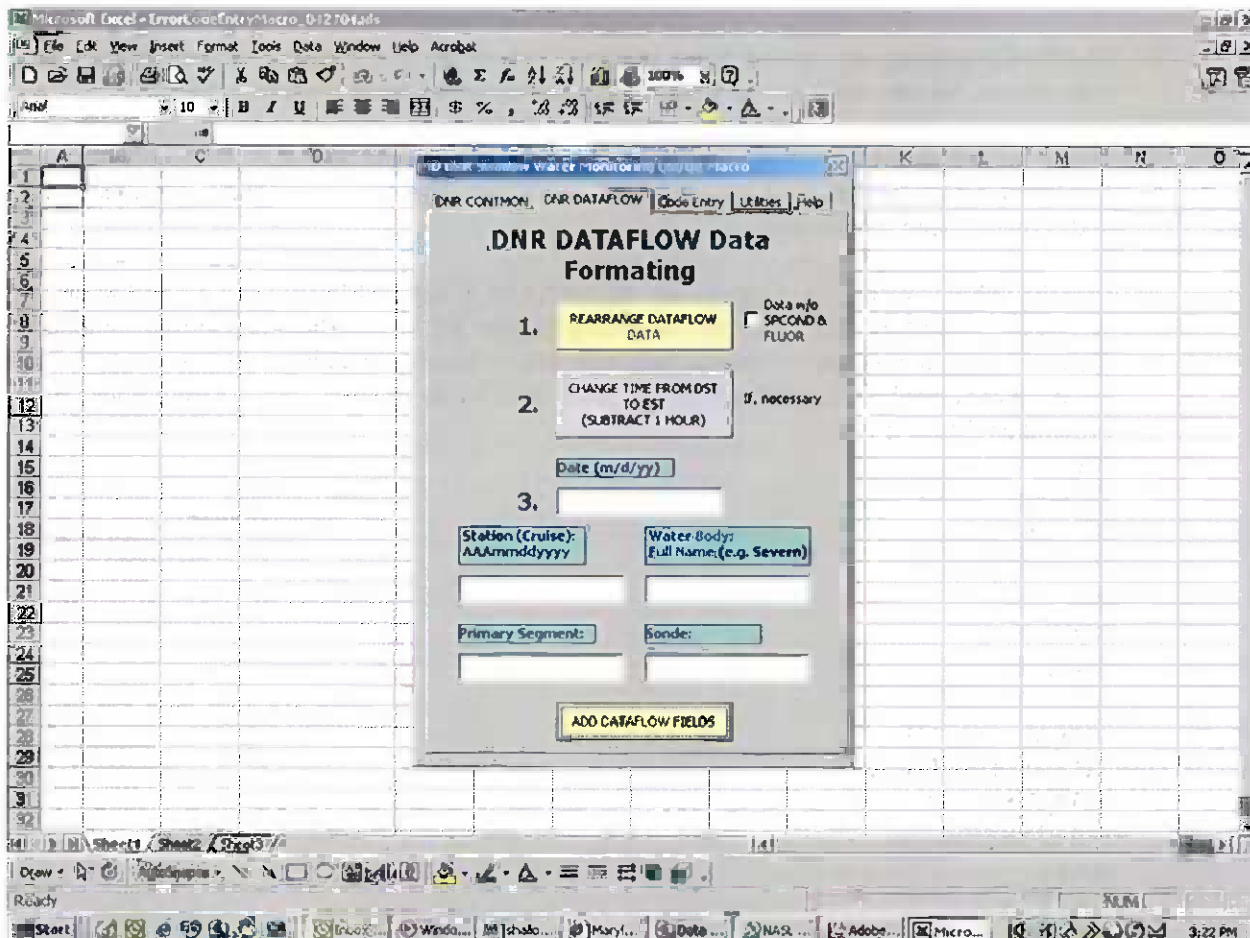


Figure A15\_1. Screenshot of the QA/QC macro for continuous monitoring data formatting.

- 5) When clicked, the “REARRANGE DATAFLOW DATA” button also flags negative values with the GNV error code, flags missing data with the NND error code, highlights values outside of set tolerance levels in red (Table A14\_1 in Appendix 14), and returns an overview summary of exceedances (Figure A14\_2 in Appendix 14). Tolerance levels are purposefully large to accommodate the diversity of data collected throughout Maryland’s Coastal and Chesapeake Bays.

Enter the Date, Station, Water Body, Primary Segment and Sonde information for the deployment being reviewed into the macro dialog box and click “ADD DATAFLOW FIELDS”. This inserts these parameters into each record.

6) Flagging Values with the QA/QC Macro:

Sound data management practices dictate that data should never be deleted. As such, we employ a data management system in which all original data values are retained in the database, but erroneous data are masked with an error code (see Appendix 13 for list of error codes). Each parameter value field also has an error code field associated with it and is designated with the suffix “\_A” (e.g., DO\_A). Error codes should only be written to the error code fields. Comments should only be written to the COMMENTS field. Because the data file is comma separated, a comma should never be used to separate comments in the COMMENTS field; a semi-colon can be used instead. The following steps outline how the QA/QC Macro can be used to insert error codes and comments.

- a) Go to the “CODE ENTRY” tab of the QA/QC macro to access all of the tools necessary to enter error codes and comments in selected cells (Figure A14\_3).
- b) Use the “SELECT CELLS” box to select the cells of the spreadsheet in which you want to enter error codes or comments.
- c) After the cells have been selected, choose a “PREDEFINED CODE” or “CUSTOM CODE” by selecting the appropriate button.

*NOTE: Custom codes should only be used for comments. They should never be used for error codes because the database only recognizes predefined error codes.*

- d) Select either a “PROBE SPECIFIC”, “GENERAL PROBE”, “NON-PROBE” or “COMMENTS” code by clicking the appropriate radio button, or if applicable, type in a custom comment.
  - e) Select the appropriate code and click the “ENTER CODE” button.
  - f) Repeat Steps b-e as necessary.
- 7) Using the procedures outlined above in Step 7 to flag data, identify any suspicious data by inspecting the values flagged in red and the original data graphed in Ecowatch. Common anomalies include abnormal spikes in chlorophyll and turbidity, abnormal dips in specific conductance, and abnormally high dissolved oxygen readings due to high dissolved oxygen charge. Post-calibration and *in-situ* field checks should also be used to identify when probes are reading incorrectly.

*NOTE: Do not be too quick to flag data. Flagging data is necessary to remove obvious outliers from the data set. Strange things can and do occur in Maryland waters, and we do not want to flag an anomaly just because it seems out of place. Anomalies should be identified, but must not be flagged unless there is proper justification. If you feel a period of data is questionable, but should not be excluded, keep it unflagged in the data set, but mention it in the comments field.*

- 8) Once all of the error codes and comments have been entered into the data file, close the macro and save the file as a Comma Separated Value (.CSV) file using the same naming convention as above with a “Q” added to the end (e.g., SEV05242004Q.csv).

The resulting .CSV file can then be imported into DNR's database.

There should be two files when a data set is complete. In our example, these files would be:

SEV05242004.csv (Raw data - no editing),

SEV05242004Q.csv (Final QA/QC'd file with erroneous data masked)